A NOVEL PHYSIOTHERAPY TREATMENT THAT ALTERS CONTROL STRATEGY IN VERTICAL JUMPING

A BACKGROUND LITERATURE REVIEW

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INTRODUCTION

This background review has been undertaken as part of research studying a concept new to physiotherapy. The concept has been termed neuromuscular energising therapy (NET) and is based upon the principle of proprioceptive communication between therapist and patient, and the transfer or flow of energy within the patients neuromuscular system. For this review an explanation of the theory behind the concept will be limited to looking at proprioception and energy flow within the body. Researchers from diverse fields have generated a large body of work covering the area of proprioception. This review will examine proprioception as it relates to physiotherapy and movement theory. There is little literature examining the concept of energy flow and most of that which is available is based upon unresearched work. This does not invalidate it but merely shows that more work is needed in this poorly understood area.

The review will also encompass the remit for undertaking the research, why jumping was chosen as a test to study NET, how the test will be measured, and what information should be gained from this measuring. It also aims to highlight recent research in the area of human jumping performance, and establish a tentative, working hypothesis for the basis of NET. It is hoped to produce an informed but speculative argument concerning the basis of NET. Some of the argument is based on indirect evidence, because direct evidence is not yet available and may be difficult, if not impossible, to obtain. It is not intended to be a comprehensive review of the literature in all the areas covered. A comprehensive review of the literature on strength and control in human vertical jumping is, however, within the scope of this paper.

The practice of physiotherapy is based on a body of knowledge that incorporates relevant information from other sciences and disciplines. In one sense this is a strength, in another it is a weakness. The incorporation of other disciplines knowledge into physiotherapy practice has often observed the separate and distinct theories of the unique body of knowledge that distinguishes physiotherapy from these other disciplines (Cott et al, 1995). Physiotherapists, unlike other disciplines, conceptualise movement on a continuum that incorporates physical and pathological aspects of movement with social and psychological considerations. Fig. 2. shows the multidimensional movement continuum proposed by Cott et al (1995).

This paper will examine part of the movement continuum by reviewing the literature on research into human vertical jumping. Previous research on jumping has addressed the factors of control and strength, and has included studies based on computer models. There is a lack of work examining the factor of control in jumping. Studies have concluded that the control element in jumping is as important as the strength factor (Bobbert and Van Soest, 1994), but have been at a loss to explain how this may be manipulated in the laboratory, and have been limited to examining it through the use of computer modelling. Based upon empirical clinical evidence it would appear that NET is a way of manipulating the control factor in human movement. So the question is, can NET alter vertical jump height by changing control parameters?

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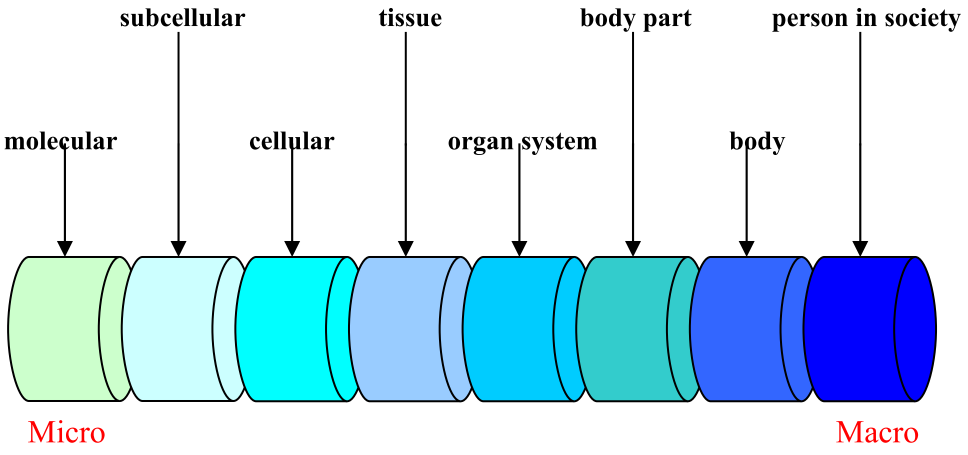

Continuum of Movement

Fig. 1. Multidimensional movement continuum. (Cott et al, 1995)

PREVIOUS RESEARCH ON JUMPING

1) Overview

Human movement demands the co-ordination of many muscles. Understanding how and why the body co-ordinates muscles has occupied the minds of researchers in disciplines from sport, the performing arts, engineering and medicine (Zajac, 1993). Human movement is complex, neuromuscular excitations, muscle force trajectories, and muscle joint torque trajectories must be transformed into joint angular accelerations and movement trajectories. The position, orientation and motion of the body segments at any instant depends on the previous history of applied forces and not just the current muscle forces, it is a dynamic system (Zajac, 1993).

The problem of analysing such a complex ballistic movement as vertical jumping has been tackled in many ways. The research can be roughly divided into two areas. In the first, studies have described the complex biomechanics of the movement (Bobbert and Van Soest, 1994; Zajac, 1993; Hudson, 1986; Bobbert et al, 1996; Selbie and Caldwell, 1996; Lees and Barton, 1996; Fukashiro and Komi, 1987; Fukashiro et al, 1995; Prilutsky and Zatsiorsky, 1994; Robertson and Fleming, 1987). Even amongst these individuals the movement has been further analysed and scrutinised. Assessing the contribution of the free limbs to the generation of vertical velocity (Lees and Barton, 1996). Determining the energy flow of the lower limb during vertical jumping, (Fukashiro and Komi, 1987). Analysing whether different starting postures affect overall jump height (Selbie and Caldwell, 1996), and analysing how the movement of segments is co-ordinated in the vertical jump, (Hudson, 1986; Zajac, 1993).

In the second research has tended to come from the field of sport and exercise where the question asked has been, which type of training is the best to improve jump height? Many authors (Avela et al, 1996; Horita et al, 1996; Fowler et al, 1995; Kramer et al, 1993; Kyrölänen and Komi, 1995; Brown et al, 1986; Vandewalle et al,1987) have tried to ascertain whether plyometric training has any significant affect on altering jump height as compared to other methods of exercising such as weight training, cycling, and running.

There has been other research too looking at the action of tendons during jumping (Prilutsky and Zatsiorsky, 1994; Anderson and Pandy, 1993; Fukashiro et al, 1995). The percentage body fat of an individual and their jumping ability, (McLeod et al, 1993; Thomas et al, 1996) and somatotype and vertical jump (Carlson et al, 1994).

Despite the amount and diversity of research that has been done on vertical jumping many questions remain unanswered and a number of issues hotly contended. Anderson and Pandy (1993) contend that elastic energy storage and utilisation enhance jumping efficiency for both counter-movement jump (CMJ) and squat or static jump (SJ). Zajac (1993) remains to be convinced of this fact and Bobbert et al (1996) argue that it is the dynamics of force development that determine the differences in the amount of work produced, not the storage and reutilisation of elastic energy.

2) The Analysis of Jumping

a) Types of Jump

The types of jump studied fall into two categories, the countermovement jump (CMJ) and the static or squat jump (SJ). Fukashiro and Komi (1987) have defined these jumps as follows:

i) CMJ

A maximal vertical jump from an erect standing position with a preliminary countermovement. Bobbert et al (1996) define countermovement as; a movement in a direction opposite to the goal direction.

ii) SJ

A maximal vertical jump from a squat position without countermovement - performed as a pure concentric contraction.

The height attained using these methods has been defined as the difference between the height of the mass centre of the body at the apex of the jump and the height of this mass centre when the subject was standing upright with heels on the ground (Bobbert et al, 1996).

Much research has been undertaken to ascertain the difference between these two types of jump in terms of height achieved. Some have concluded that CMJ produces greater height gains than the SJ and that this might be attributed to the difference in work done by the hip extensors (Fukashiro and Komi, 1987). Bobbert et al (1996) believe that the greater height gains in CMJ are achieved because the countermovement allows muscle to build up a high level of active state and force before the start of muscle shortening. Thus the muscles are able to produce more work over the first part of their shortening distance. From their research they ruled out the effect of storage and reutilisation of elastic energy for the enhanced performance of CMJ over SJ. However, Anderson and Pandy (1993) concluded that elastic tissues did have a role to play and that this was to effect a more efficient conversion of musculotendon energy into translational, kinetic, and potential energy of the skeleton. So elastic energy storage and utilisation affects efficiency much more than jump height. However, they also concluded that it was difficult to resolve, with any accuracy, differences between SJ and CMJ. They believe that body position at the start of jumping is a major determinant of jump height, but Selbie (1996) has refuted this.

Many of these experiments have imposed limitations upon subjects in terms of how the arms are used within the jump. Some constrain subjects to keep their hands held behind their backs (Bobbert et al, 1996). This contrasts with the work of Lees and Barton (1996) who studied the contribution the free limbs make to jump height by allowing subjects to naturally swing their arms upwards. It could be argued that any study of human movement should put no constraints upon the way the subjects jump in order to determine the true contribution of the many factors that combine to produce vertical jumping in human subjects. It should be noted though, that constraints are placed upon experiments so that the biomechanical models used to compute and interpret the data generated from such experiments can be simplified.

b) Models

Much of the research undertaken on the biomechanics of jumping uses one of two models to interpret the experimental data.

i) Forward Dynamics

A forward dynamics representation of the body emulates how neuromuscular control signals actually produce movement (Zajac, 1993). This approach is less used due to difficulty in finding a set of neuromuscular control signals, or the muscle forces that such signals produce, that when input into a forward dynamics model, produce a co-ordinated simulation of the movement.

ii) Inverse Dynamics

Models based on this approach are used more extensively as they use more easily measurable data, such as body joint angles, net joint torque's produced by muscles, and external forces such as ground reaction force can be input to the model. However, actual individual muscle forces cannot be resolved using this model and assumptions have to be made about how each muscle relates to the net joint torque at a given instant. Unfortunately these assumptions may have little physiological basis. Even if estimation of the forces was correct, inverse dynamics models cannot be used to ascertain how these forces affect the motion of joints (Zajac, 1993).

This fact is evidenced in the work of Selbie and Caldwell (1996), who by using a forward dynamic simulation model and an optimisation search field approach, found that very similar jump heights were achieved with very different torque onset times. This factor may have been missed using an inverse dynamics approach. An optimisation search field gives the advantage of allowing a large range of optimal solutions to be studied whilst another factor, such as initial posture, is systematically varied.

The way forward dynamic models are used to produce the best possible simulation compatible with the measured kinetic and kinematic data is as follows:

- Formulation of a forward dynamics model.
- Collection of kinesiological data (body segment position, ground reaction forces and EMG trajectories).
- Computation of neuromuscular excitation (EMG) trajectories, which best fit the collected data.
- Analysis of the EMG, force, and kinematic simulated trajectories.

In this way an understanding of the task being studied, for example co-ordination, can be arrived at (Zajac, 1993).

It must be remembered though that inspite of highly accurate data collection and complex modelling approaches, it is still very difficult to determine why the central nervous system (CNS) co-ordinates muscles the way it does. This approach merely allows us to break down into very fine detail the "what" of what is happening and to a greater extent the how; the why still remains elusive. Simulations are imperfect but by analysing the imperfections any assumptions that need to be reconsidered can be reviewed. Eventually by using this method, a better model of the neuromusculoskeletal control system should become available.

c) Data Collection and Equipment

Despite the large amount of work done on jumping there is no form of agreed protocol that has been worked out in terms of the number of subjects to use, or the number of jumps to undertake. From one to twenty two subjects have been used from whom to gather data, which calls into question the validity of some of the studies based on small population samples, such as the work by Fukashiro and Komi, 1987. However, one apparent factor towards standardisation is that often these individuals will participate in a sport that includes jumping as part of its discipline. This is to rule out the learning effect of the motor task during the experiment (Bobbert et al, 1996; Hudson, 1986; Bobbert and Van Soest, 1994; Baker et al, 1994).

Subjects are then familiarised with the jumping procedure (Fukashiro and Komi, 1987; Anderson and Pandy, 1993), and then a series of from three to five or more jumps is made (Fukashiro and Komi, 1987; Anderson and Pandy, 1993; Bobbert et al, 1996). Three or more jumps improves the test-retest reliability coefficient, especially in untrained subjects (Vandewalle et al, 1987). The vast majority of studies have collected data of the same type in similar ways. Collection from electromyograph (EMG), force plates and high-speed cameras provides data on muscle action, timing, and ground reaction force vector. From this positional data, locations of joint axes and segmental mass centres and angular accelerations of segments can be calculated.

EMG data is then used to input into either a forward or inverse dynamic model and is used to give the timing of muscle inputs in the movement being studied. From six to eight muscles are usually measured and these normally include; gluteus maximus, rectus femoris, gastrocnemius, soleus, hamstrings and vasti (Anderson and Pandy, 1993; Bobbert et al, 1996; Bobbert and Van Soest, 1994; Jacobs et al, 1996).

3) Strength and Control in Jumping

Zajac (1993) asked the question, "Is jumping height more sensitive to muscle strength or to speed?" He then answered his own question by stating that, "If you could choose between the two, strengthen your muscles rather than condition your muscles to be faster." He only based this statement on research he conducted with Pandy (1989) on squat jumps, as CMJ were not studied. His studies also revealed that it can be suggested that uniarticular extensor muscles provide most of the propulsive mechanical energy, uniarticular flexor muscles are virtually non-participatory and that biarticular muscles fine-tune the co-ordination. However, results from a study by Jacobs et al (1996) and supported by previous work from Fukashiro and Komi, (1987) and Hudson, (1986) suggest that biarticular muscles contribute to a net transfer of power (or inflow of energy) from proximal to distal joints during explosive leg extensions. This causes an efficient conversion of body segment rotations into the desired upward translation of body centre of gravity. However, Bobbert and Van Soest (1994) further qualify the matter through a simulation study of the effects of muscle strengthening on vertical jump height. They suggest that in order to take full benefit of increased muscle strength, control needs to be adapted. That is to say that it is not only important to strengthen the muscles, but unless these stronger muscles can be utilised most efficiently and effectively by the body, gains in strength that have been made will be of little benefit in attempting to gain greater jump heights. This was also seen in a study of different strength training exercises done by Baker et al (1994). They concluded that improvements in maximal strength do not necessarily equate to improvements in jumping and it has yet to be determined if this effect lies in the muscle or the nervous system.

a) Strength

Increases in strength may be attributed to a combination of neural and hypertrophic adaptations. The neural adaptations are thought to be the dominant initial mechanism for strength increases, but after several months of training the hypertrophic adaptations become more dominant (Jones and Round, 1993; Baker et al, 1994; Rutherford and Jones,1986). To produce the greatest performance gains exercises must match functional activity, i.e. training must be specific such that faster exercise best improves fast athletic movements, although isometric exercise can improve actions like the vertical jump which begin slowly (Morrissey et al, 1995).

This finding fits with that of Baker et al (1994) who state that maximal strength improvements do not necessarily equate to improvements in power activities such as vertical jump. They say that the reasons for this are not clear but from the work of Bobbert and Van Soest (1994) it could be argued that it is the ability to maximally utilise this new found strength, through improved control, that is key. Other studies have concluded that a large part of the improvement in the ability to lift weights is due to an increased ability to co-ordinate other muscle groups involved in the movement, such as those used to stabilise the body (Rutherford and Jones, 1986). It is in influencing these factors that it is believed NET will affect vertical jump height.

In one study it was reported that plyometric training (depth jumping from a height of 40cm) appeared to maximise the co-ordination of neuromuscular skills and muscular strength. It was thought that whilst more strength may be developed through weight training alone, the transfer of such strength to jump performance was questionable (Brown et al, 1986). Increases in jump height attained from use of strength training programmes have varied largely from study to study and at best remain inconclusive (Avela et al, 1996; Horita et al, 1996; Fowler et al, 1995; Kramer et al, 1993; Kyrölänen and Komi, 1995; Brown et al, 1986; Vandewalle et al,1987; Bobbert and Van Soest, 1994). In their simulation study Bobbert and Van Soest (1994) went on to show that although muscle strength does determine the maximal jump height that can be reached, actual performance relies crucially on the tuning of control to muscle properties. It is all very well changing the muscle properties but subjects have to be able to use the changed muscle effectively.

b) Control

Few researchers have acknowledged the importance of the control factor in jumping (Bobbert and Van Soest, 1994). Many have failed to adequately define their terms and in some instances it becomes unclear as to whether they mean control or co-ordination (Zajac, 1993; Hudson, 1986; Bobbert and Van Soest, 1994). Control in movement should not be confused with co-ordination of movement. Nearly forty years age Hellebrandt (from Jensen et al, 1994) suggested leg action in jumping was a stereotypical pattern with phylogenetic origins and from its very onset co-ordination for jumping is in place. This has been supported in more recent work (Jensen et al, 1994; Hudson, 1986).

Co-ordination refers to the organisation of a systems multiple components, how multiple degrees of freedom are brought together to result in a functional outcome. When co-ordination is stable, reproducible patterns and invariance result (Jensen, 1994). Hudson (1986) defines co-ordination as the timing and sequencing of segmental movement. Scholz (1990) defines co-ordination as the process by which movement components are sequenced and organised temporally, and their relative magnitudes determined, in order to produce a functional movement pattern or synergy.

Control refers to the scalar parameterisations of displacement, amplitude and speed. Adjustment of control variables tunes the performance to the context of the task and it's specific demands. This may also act to constrain the possible solutions for the problem and set the conditions for performance (Jensen et al, 1994).

A major problem faced by the nervous system in the co-ordination of functional motor acts has been referred to as the "degrees-of -freedom" problem. The problem is, how are the relatively limited sets of observed movement patterns reliably produced given the nearly infinite combinations of possible states or values that the neural, muscular, and skeletal components of the motor system can assume? (Yeo, 1997; Keshner, 1990). However, the potentially infinite combinations and temporal orderings of movement components give way to a very few and distinct number of movement patterns. A major goal of movement science is to discover how this effective compression from many to only a few degrees of freedom is achieved (Scholz, 1990).

Scholz (1990) goes on to state that theories of motor control and motor development have been used by physiotherapists to guide the development of specific treatment paradigms. But, in many cases, theory consists of loosely connected facts and assumptions rather than a coherent framework for generating and testing hypotheses and organising knowledge. For therapists, when teaching motor skills, those variables that can be manipulated to facilitate optimal performance have to be identified.

Human movement systems, as seen in the discussion on models of jumping, have frequently been treated as one-dimensional, single axis, rigid bodies in order to simplify the gathering, analysis and interpretation of data. The results often lead to conclusions about the production and control of movement that do not relate to the control demands placed on the CNS (Keshner, 1990). She goes on to point out that the problem is one of "equifinality", a single behaviour resulting from multiple muscle combinations. It shows that a functional movement pattern can be under the control of different motor programmes, and possibly utilise different control mechanisms, and yet still attain the same final behaviour.

For example a multisegmental, multimuscle system like the head and neck, can potentially switch its control operations between a number of reflexes, including vestibular and proprioceptive, and still achieve the appropriate co-ordinated response. This has been shown experimentally using voluntary and reflex head movements in cats. The cats responded by moving their head to track a target and the muscle activation pattern for each muscle was plotted. Response patterns of muscle activation were consistent for individual cats over several months but differed from animal to animal. However, when reflex patterns were investigated response patterns were very similar (Keshner, 1990). She also noted that the available pattern of muscle activation appeared to be more dependent on the available sensory inputs or requirements of the task, than on the mechanical advantage of the individual muscle. This finding would suggest that the central motor programme depends both on previous experience with a task, and on the individual biomechanical constraints of each subjects head-neck motor system, to organise and plan the muscle activation patterns that improve stability (Keshner, 1990).

Another way of inputting and altering motor control may be to alter the "internal model of body dynamics" (Frank and Earl, 1990). A central feature of the schema presented in fig 2. is a CNS model of body dynamics, a model of how body segments interact during movement. An example is rising onto the toes. Difficulty may be experienced as for many it is not a well-practised movement and initially they overbalance. Subjects soon learn to initially shift the body's centre of mass forward prior to rising. This shows a model of body dynamics which is state dependent, interactions between body segments changing depending upon the position of the body (Frank and Earl, 1990). If the model of body dynamics is poorly developed, as with novel movement tasks, or disrupted by damage to the nervous system, postural [or stabilising] accompaniments may be absent, inappropriate, or poorly timed.

This is shown in fig.3. and illustrates how Frank and Earl's model is let down by making too little of the importance of sensory input, proprioceptive control and proper function of sensorimotor integration. Inadequate proprioceptive stimulation from joints, muscles, skin and other structures means that no level of the sensorimotor system is facilitated to work properly. More highly mechanised and sedentary lifestyles lead to a reduction in the variety of movement which in itself decreases the proprioceptive stimulation essential for the performance of good motor patterns (Jull

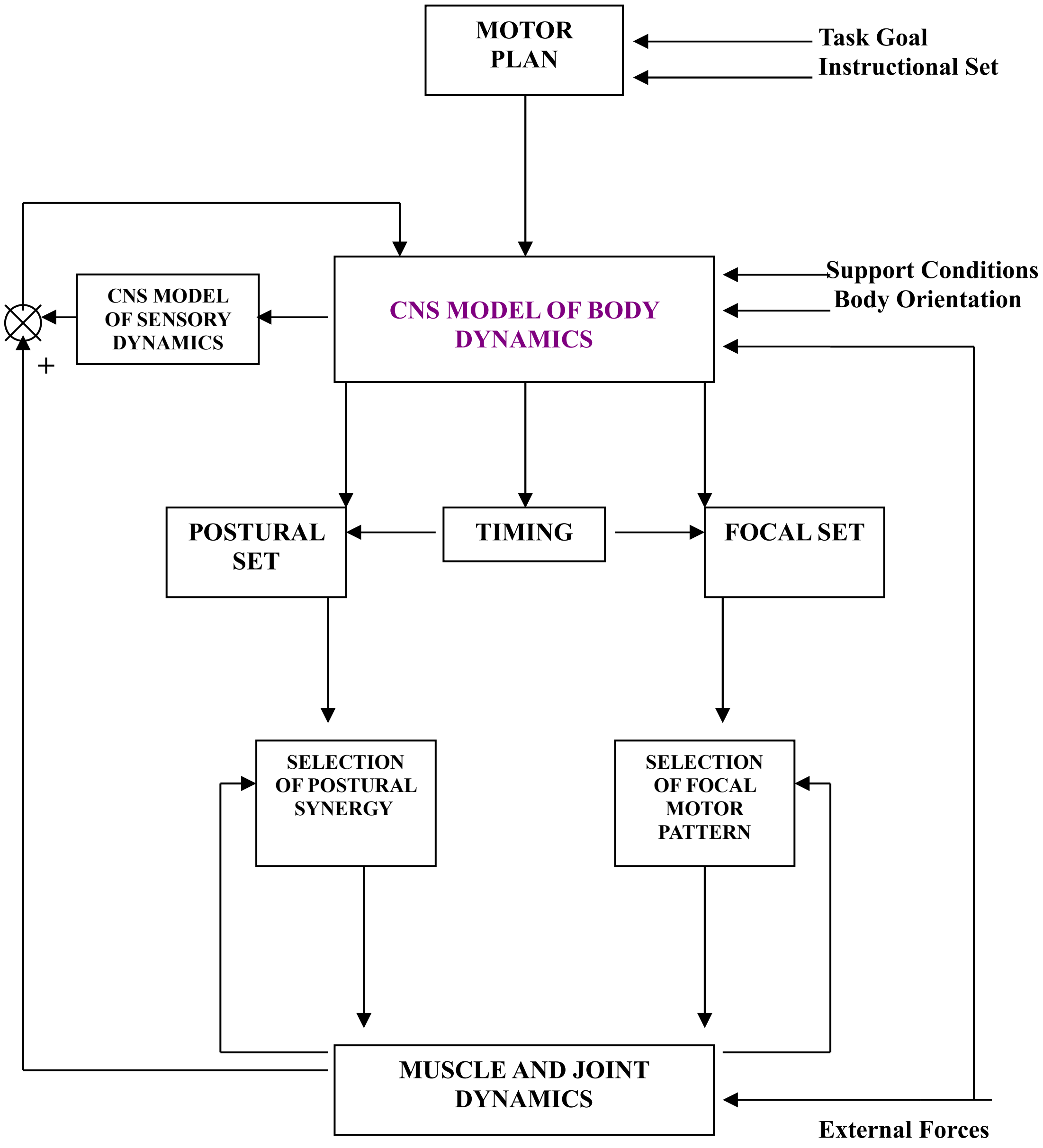

Fig. 2. A schema for the co-ordination of posture and movement. The central theme of the model is that a central nervous system (CNS) model of body dynamics translates cognitive motor plans into physical parameters for the regulation of posture and movement. (Frank and Earl, 1990).

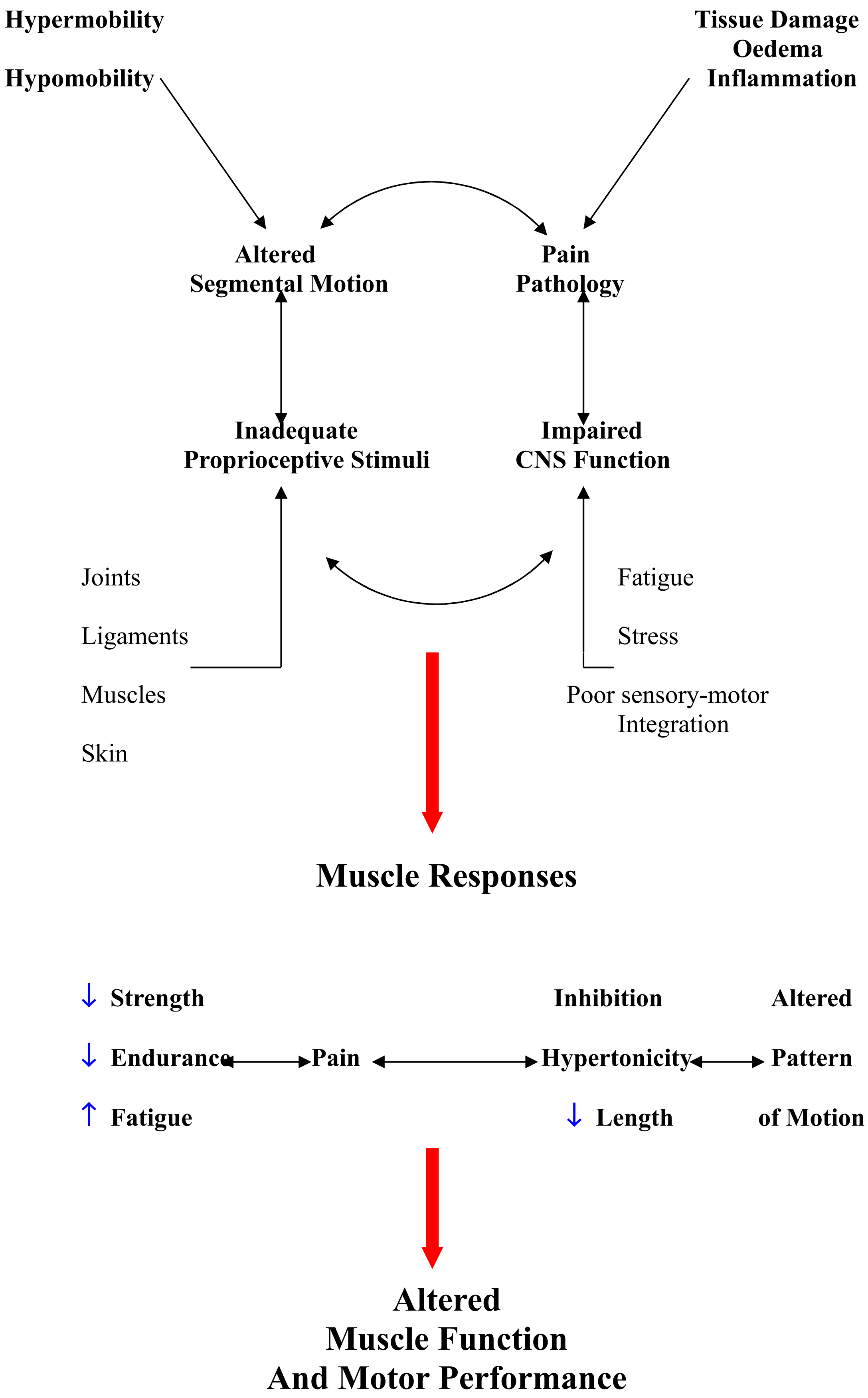

Fig. 3. Sources of adverse stimuli and muscular responses. (Jull and Janda, 1987)

and Janda, 1987). In this way joint and muscle dysfunction [or poor function] can directly impair the CNS's motor regulation. Jull and Janda (1987) go on to state that if the concept of impairment of CNS regulation of posture and movement is to be accepted, then it is reasonable to question why this impairment is incurred.

Previous research on jumping indicates that the co-ordination of the jump is stable from its inception (Jensen et al, 1994; Hudson 1986), but that individual differences lie in the control of the task (Bobbert and Van Soest, 1994), either as an expression of individual style or the inability to effectively manage the details of the movement (Jensen et al, 1994). Co-ordination is a functional and essential relationship among elements of a movement system. However, sufficient command over other control parameters tune and refine the performance. These parameters include strength, balance, perception [proprioception], motivation and an efficient and effective interplay between components of the musculoskeletal system over which the CNS is the governing element.

From what has been outlined it becomes apparent that it is not a lack of gross motor co-ordination that is exhibited in situations of sub-maximal jumping, but a lack of control. Given that the leg action in jumping is a fundamental invariant pattern of co-ordination it remains the goal of future research to determine those control parameters (or levels of the parameters) that lead to optimisation of the task.

THE TECHNIQUE

1) Overview

Neuromuscular energising therapy (NET) is a rehabilitation system in which manual handling skills are used to improve the patients posture and function by promoting and improving the patient's transfer of energy. The concept of energy transfer (or flow) between body segments has previously been identified through research (Fukashiro and Komi, 1987). It is an interactive therapy using slow, controlled movement, which creates a direct proprioceptive link into the patient's neuromusculoskeletal system, based upon a system of proprioceptive feedback between the therapist and the patient. A sense of proprioceptive touch to communicate with the patients body is very important for therapists to develop (Hartman, 1998). It requires the patient to be active in direct response to the therapists physical guidance as they take the patient through combinations of physiological movements, selected according to the patients movement deficits, and their potential for correction.

A progressive challenge is presented to the patients neuromuscular system. As movement deficits are corrected and the inflow of energy into the patient's body segments increases (Fukashiro and Komi, 1987), the therapist places gradually increasing demands on this system. The technique also activates the patients balance reactions creating economical movement patterns. When the therapist feels that the patient's energy is sufficient to do the work required, the body segment is "suspended". The therapist removes their hands from the patient who is instructed to hold the position. In this way the patients neuromuscular system is fully engaged.

Repetition of the process brings about progressive adaptation and improvement of the patients movements and control of movement (King, 1998).

Proprioceptive contact enables the patient to echo the movement the therapist is inputting. When an input movement is not output exactly by the patient, a problem has been highlighted. Energy is said to flow (or be transferred), when the patient achieves smooth segmentaly well-controlled movement. This energy flow is said to be blocked when the patient is unable to achieve such physiologically normal movement. By heightening proprioceptive awareness the patient is able to fine-tune their segmental control and so enhance their functional ability (King, 1997).

2) Proprioception

Proprioceptors are those receptors in the body that measure the actions of the organism itself, not those imposed by the outside world, they impart a conscious awareness of body position (Lephart and Fu, 1995). Spinal alpha motoneurons can respond to error messages by adjusting the length of muscles through the stretch reflex, but it is effective only for small adjustments of postures and slow movements (Brooks, 1986). Joint, muscle, tendon, and skin receptors mediate position sense but more recent findings suggest muscle spindle afferents appear to play the more crucial role in mediating sense of position (Marks, 1997).

A deficit in the ability to process positional information might impair motor control or predispose an otherwise healthy individual to injury, the consequences of which are shown in fig.4. Inadequate proprioceptive stimulation from joints, muscles, skin and other structures means that no level of the sensorimotor system is facilitated to work

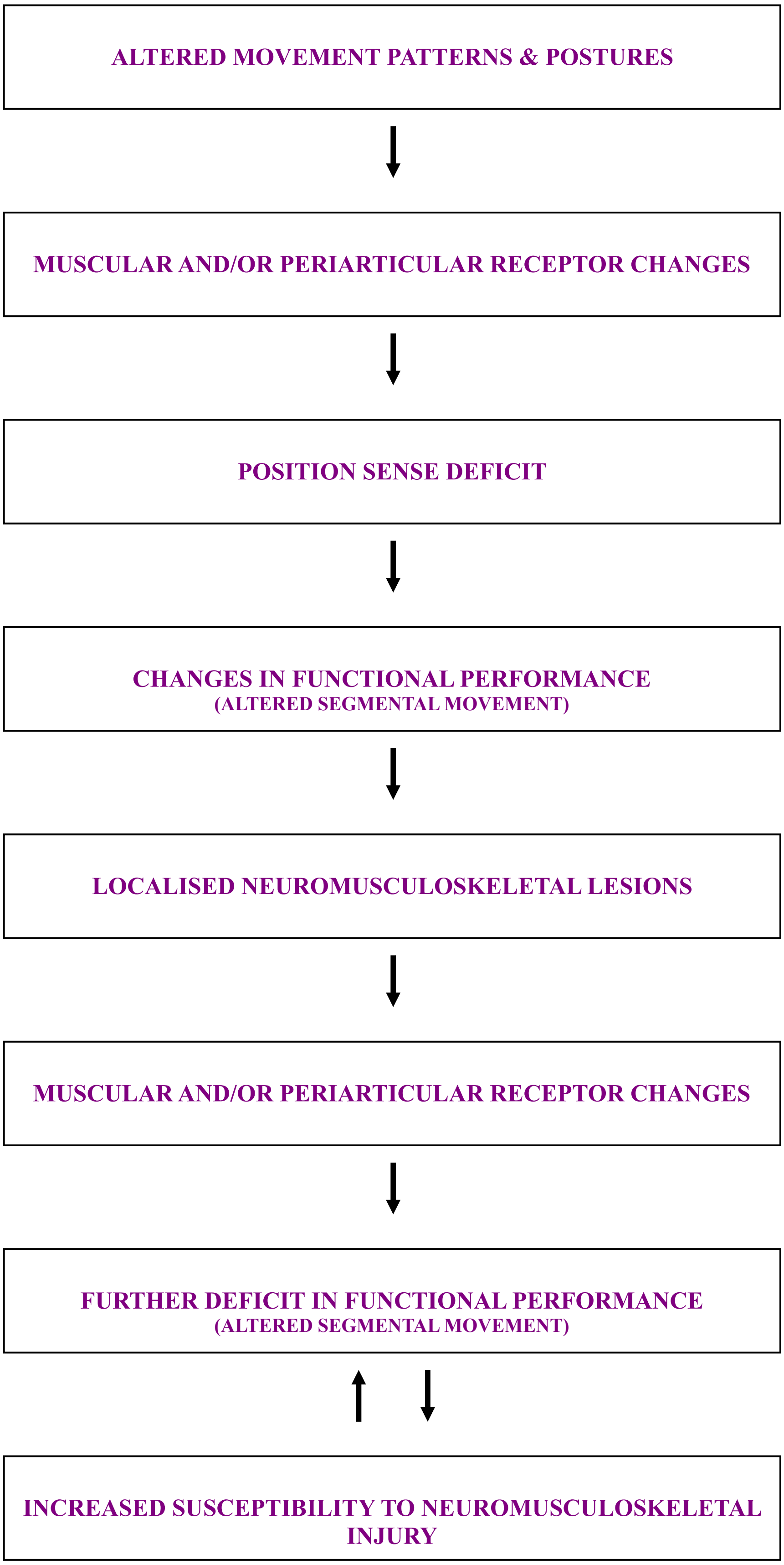

Fig. 4. Schematic representation of possible causes and consequences of impairment in joint position sense. (Adapted from Marks, 1997).

properly (Jull and Janda, 1987). They go on to state that the importance of adequate sensory input, proprioceptive control and proper function of sensorimotor integration has probably been underestimated in the pathogenesis of low back pain [and movement dysfunction]. For this reason proprioceptive facilitation techniques should be included in the therapeutic program for those suffering from low back pain syndromes [and movement dysfunction] and postural defects. NET may be used to address this problem as shown in fig.5. and has been used successfully to treat patients suffering from low back pain (King, 1998).

It is difficult to determine the degree to which normal accurate position sense may depend upon the convergence of differential inputs from articular as well as muscular and tactile afferent channels (Marks, 1997). He goes on to state that if muscle spindles do play a more major role than previously thought an alteration in surrounding muscle spindle stretch sensitivity could cause a decrease in a subjects ability to accurately position a joint. Selectively inhibiting inputs known to reduce spindle stretch sensitivity, if deemed excessive, whilst promoting those known to enhance spindle stretch as required, should improve an impaired subjects positioning performance. There appears to be a strong contribution of muscle spindle afferents to position sense, and the possibility that these receptors are supported in this function by activity of some joint and skin receptors. It would therefore seem logical to conclude that therapeutic programmes aimed at improving aberrant positional feedback should be designed to promote optimal activation of muscle, skin and joint afferents (Marks, 1997). By using both light and firm pressure on the skin, positioning joints and recruiting muscles through slow, controlled movement, NET fulfils these criterion.

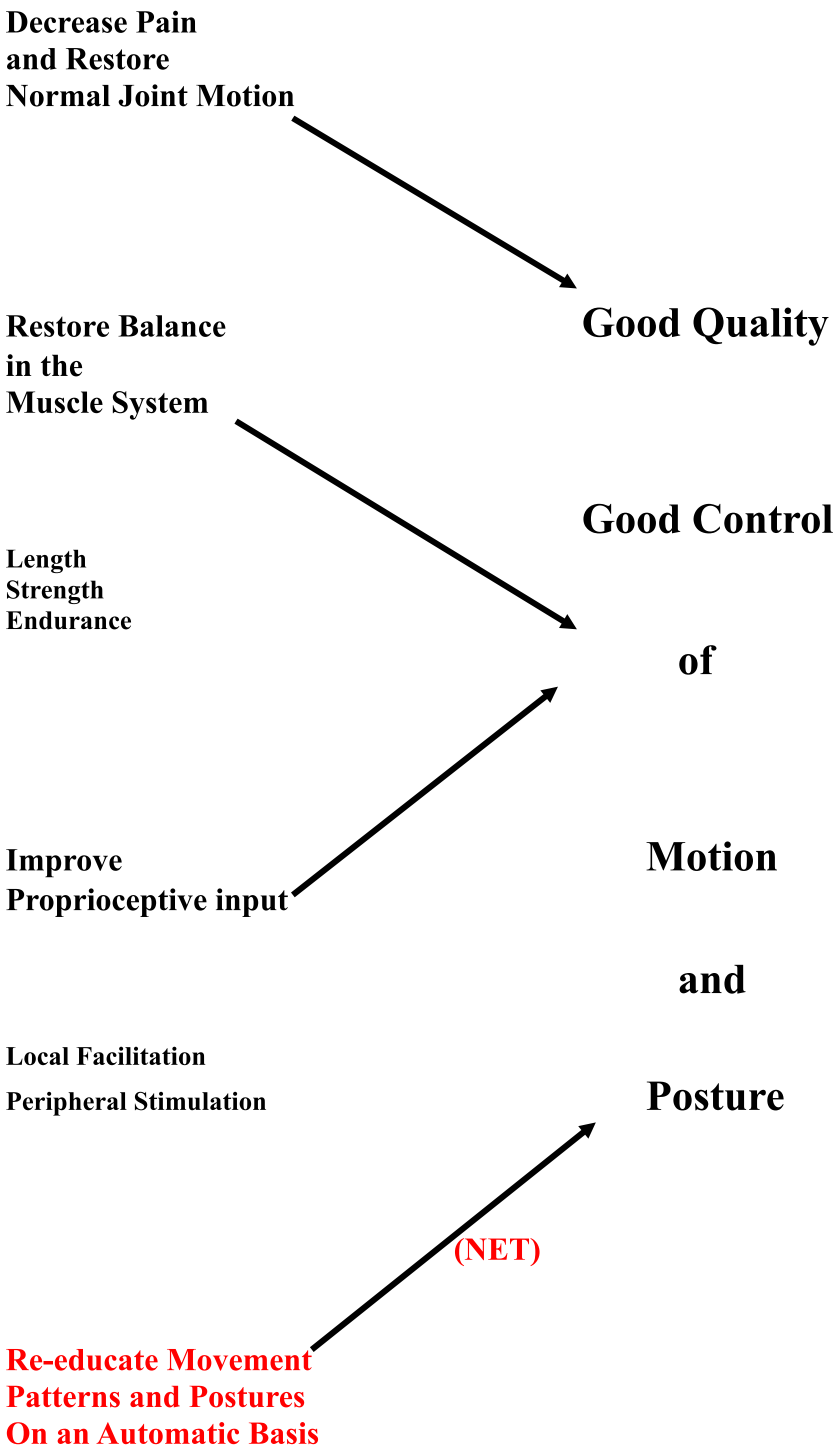

Fig. 5. Remedial measures used to achieve good motor control. (Jull and Janda, 1987)

A passive technique which addresses this problem can be found in strain and counterstrain. It is aimed at reducing and arresting inappropriate proprioceptor activity, which can maintain somatic dysfunction. It is a passive treatment not directed toward tissue injury or damage but aberrant neuromuscular reflexes within that tissue. Specifically, the primary proprioceptive nerve endings are singled out as reporting false information to the central nervous system and maintaining somatic dysfunction (Bailey and Dick, 1992). NET confronts the same issue but as an active treatment it does so more holistically allowing the patient to normalise aberrant movement patterns that have resulted from the somatic dysfunction .

In the spinal cord, sensory information from articular, muscular and cutaneous receptors connect with spinal interneurons and ascend to supraspinal centres involved in sensory appreciation and motor control (Yeo, 1997). Abnormal joint movement, and loss of sensory information from muscle and skin receptors causes the generation of abnormal afferent information. This leads to the decrease in excitability of alpha motoneurons activating muscle. This reduced voluntary activation of muscle is defined as a failure to fully activate an uninjured muscle that acts across an injured joint during a maximum voluntary contraction. This phenomenon can cause muscle weakness by preventing maximal force generation, which if prolonged, may result in muscle fibre atrophy (Hurley, 1997).

Taking the point of Jull and Janda (1987) referred to previously, it need not just be joint damage that can cause such a phenomenon. Fig.6. shows what could theoretically happen in the absence of apparent damage, where the key dysfunction has not been identified. So, decreases in alpha-gamma motoneuron excitability, as

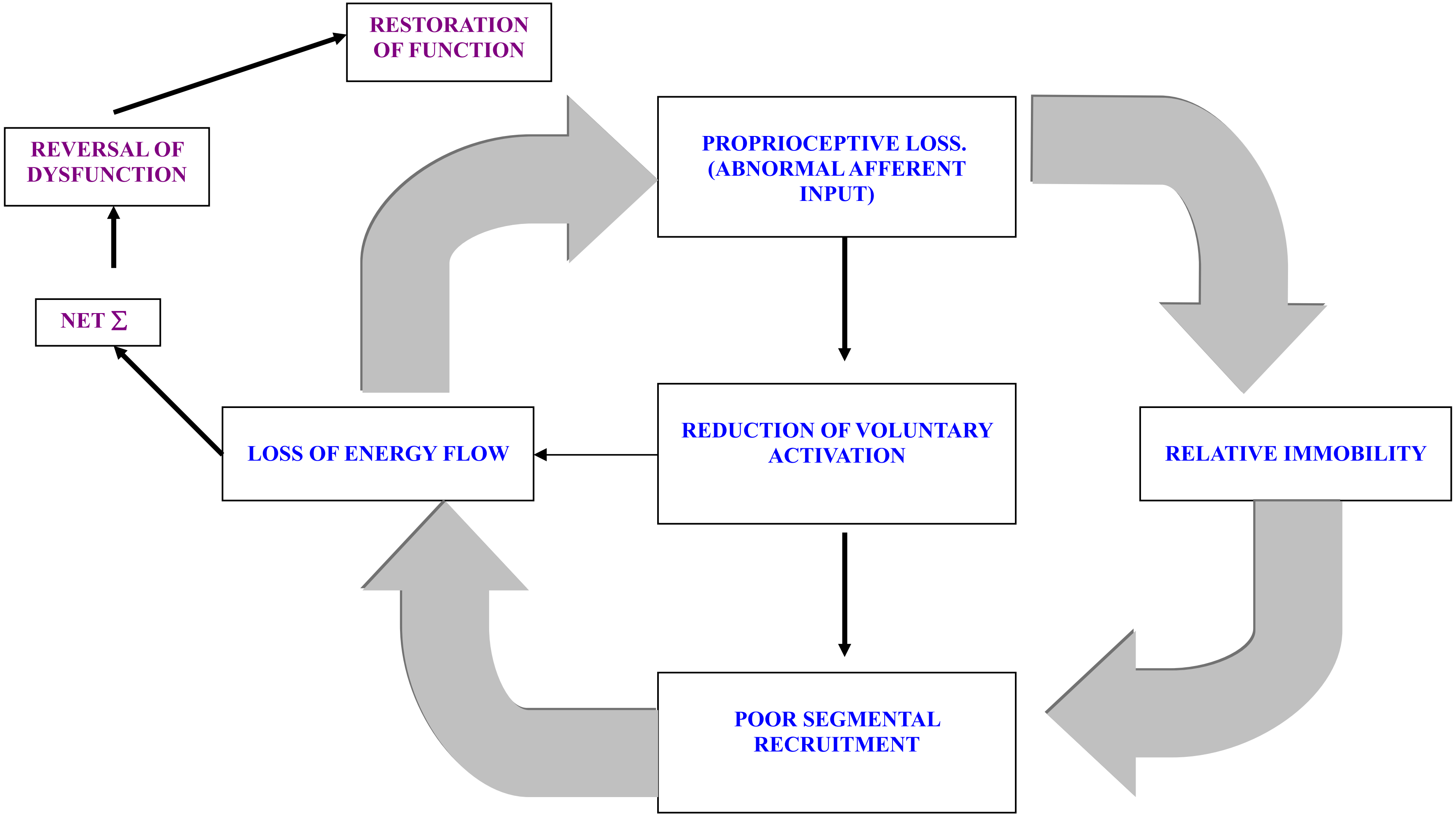

Fig. 6. Consequences of Proprioceptive loss. (Adapted from Hurley, 1997)

well as reducing voluntary activation, could also decrease muscle spindle sensitivity and hence proprioceptive activity (Yeo, 1997; Brooks, 1986; Hurley, 1997). Where normalisation of afferent information improves muscle spindle sensitivity, an increase in alpha-gamma motoneuron activation could improve proprioceptive acuity leading to improvements in functional ability (Brooks, 1986; Hurley, 1997). These are currently speculative hypotheses whose validity needs to be determined. This highlights the importance of muscles as an organ of proprioception, with a vital role in the appreciation and control of movement. It also highlights the importance of incorporating the re-education of neuromuscular skills into the rehabilitation regime (Lephart and Fu, 1995; Hurley, 1997).

3) Energy Flow

The idea of energy flow within the human body is not a new concept. It has been present for many centuries in Eastern medical tradition. One such traditional system is that of Chi Kung. Chi means energy and Kung means motion or movement. The Chinese have sequenced together various movements whose regular practice allows energy to flow freely through the nervous system, thus energising the body to perform at more efficient levels (Kaul, 1996).

This idea or concept of energy seems very alien to traditionally educated Western minds and as such well-researched articles are scarce. Fukashiro and Komi (1987), acknowledge that "less effort has been given to the detailed examination of the vertical jump regarding the exchange of mechanical energy within body segments, the transfer of energy between body segments, and the power flow from the muscle". In their study they found that "the inflow of energies to segments were found in the sequence of the thigh, then the shank and finally the foot", implying that energy flowed from the upper segments to the lower segments in SJ and CMJ.

This is a more western way of looking at energy. It is very different to the notion that there is a subtle field of energy around the human body, a halo-like envelope of light that exists just beyond the normal human perception and which can be found in many ancient traditions (Talbot, 1991). An explanation for this may be that it is the result of the body's internal chemistry, which produces varied frequencies of electrical and chemical energy in the body. This could create varying degrees of heat within the physical body, which may, by some, be interpreted as energy layers. Many alternative healers assert that there are seven main layers of energy, which if damaged can result in damage at the cellular level within the physical body (Kaul, 1996).

THE RESEARCH

1) Overview

Whilst research in the field of motor control presses ahead, discoveries continue to be made by clinicians practising in the field of rehabilitation. Often faced with a lack of well-researched fact upon which to base treatment strategies, these clinicians needs must rely upon empirical clinical evidence. In this last section the review will encompass the remit for undertaking the research, why jumping was chosen as a scientific test, how the test will be measured and what information should be gained from this measuring.

It has been my good fortune to work with a clinician who has continued to question and challenge his clinical practice and to push forward the boundaries of accepted knowledge. Over the past ten years he has developed skills and techniques in the field of neuro-rehabilitation to the point where it can be said that a new treatment concept has evolved. Circumstances have contrived to allow this new concept to be researched and evaluated in the laboratory. The therapist discovered he could make an individual jump higher using the treatment. The researcher discovered that the aspect of control in jumping has been shown to be of great importance, but previous researchers had found no way of being able to manipulate it. Equipment capable of very accurately measuring such a complex ballistic movement was available to study the problem. Where previous researchers have been able to systematically manipulate the muscle strength aspect of vertical jump height it now appears that a way of manipulating the control aspect and for measuring it has been found.

So far there has been no research done to show techniques that can affect subjects control of their musculoskeletal system. Repeated practice is currently the only method advocated for improving co-ordination and control. Research by Bobbert and van Soest (1994) has shown the control element of jumping to be critical in gaining maximum jump heights. This research hopes to carry forward the previous work by taking the computer model concepts and applying them practically in the laboratory. So this research will make a practical advance of the previously theoretical work undertaken by Bobbert and van Soest (1994) and may open up further areas of research that could not previously be explored due to the lack of a technique for successfully altering subjects control strategies.

2) Why Jumping?

The purpose of this research is to determine whether the claims of a novel physiotherapy treatment technique to improve motor performance in the clinic can be substantiated through laboratory testing. The vertical jump height has been chosen as it has been used clinically to show improvement in the performance of normal subjects. As has been shown previously the research on jumping is quite extensive (Bobbert and Van Soest, 1994; Zajac, 1993; Hudson, 1986; Bobbert et al, 1996; Selbie and Caldwell, 1996; Lees and Barton, 1996; Fukashiro and Komi, 1987; Fukashiro et al, 1995; Prilutsky and Zatsiorsky, 1994; Robertson and Fleming, 1987; Avela et al, 1996; Horita et al, 1996; Fowler et al, 1995; Kramer et al, 1993; Kyröläinen and Komi, 1995; Brown et al, 1986; Vandewalle et al,1987). and from this a valid protocol could be developed with which to test the hypothesis.

3) Why Coda?

Coda was chosen because by using infra red markers placed on the subject's body it gives a three-dimensional representation of the body in time and space. Three cameras read the markers and generate data giving vertical, horizontal and depth displacements. By judicious placement of markers on subjects their centre of mass can be accurately worked. In this way the height attained, previously defined as the difference between the height of the mass centre of the body at the apex of the jump and the height of this mass centre when the subject was standing upright with heels on the ground (Bobbert et al, 1996), can be determined. As well as being able to determine subject's jump heights the Coda can also be used to analyse which joints are activated, and in what sequence, during the jump.

PROTOCOL

Hypothesis:

Using a novel physiotherapy treatment to influence the control strategy in vertical jumping, greater vertical jump heights will be achieved by test subjects.

Null Hypothesis:

A novel physiotherapy treatment will be unable to influence the control strategy in vertical jumping, greater vertical jump heights will not be achieved by test subjects.

Questions to be answered:

Does the treatment altar subjects vertical jump heights?

Is the change in jump heights significant?

Protocol:

1. On arrival subjects will be randomly selected to either treatment or placebo group and will sign a consent form, having had the treatment and test procedures fully explained to them.

2. Subjects will then have their height, weight and percentage body fat measured.
3. Subjects will have a standard warm-up session including stretching to minimise the risk of injury.
4. CODA markers will then be placed as per **fig.7** and pre-treatment jump test will be performed (3 jumps).
5. Subjects will then undergo either a treatment or a placebo treatment.
6. Subjects will undergo post-treatment jump test (3 jumps).
7. At a date approximately 6 weeks later subjects will return to undergo the crossover aspect of the study.

The subjects will be required to wear shorts and trainers for the treatment and testing. Surface markers will be attached to the skin with non-irritant adhesive tape.

Analysis:

The results will be statistically analysed by a paired t-test.

Convenience sampling due to time / availability of subjects.

Using sports people used to jumping to:

Reduce the learning effect in the experiment.

One group has placebo treatment where physiotherapist only places hands on limbs and moves them randomly to simulate treatment. In this way the only variable is the treatment procedure. All subjects are used to jumping in their normal sporting activities and are fit enough to undergo testing and treatment. Environment and time of day of testing will be kept the same to rule out external stresses and diurnal variations.

Statistical design.

Cross-over (change-over or shift)

Different treatment applied to the same subject in random order at different times to give a single blind design.
Done as the administration of a treatment applied during one period of time does not extend to or affect subsequent treatments applied during another period of time.

A pilot study on one subject has been conducted to determine the viability of the methodology and no problems were encountered in terms of subject safety, comfort and feasibility of the study. The treatment is non-invasive and only challenges subjects with a level of effort that they are able to cope with.

MARKERS

1. TOE
2. HEEL
3. MAL
4. KNEE
5. HIP
6. SHOULDER
7. CHIN
8. TRAGUS/JAW
9. TEMPLE
10.
11.HAND
12.WRIST
13.ELBOW
14.
15. FLOOR/ORIGIN
16.
17. T1
18. T2
19.
20.

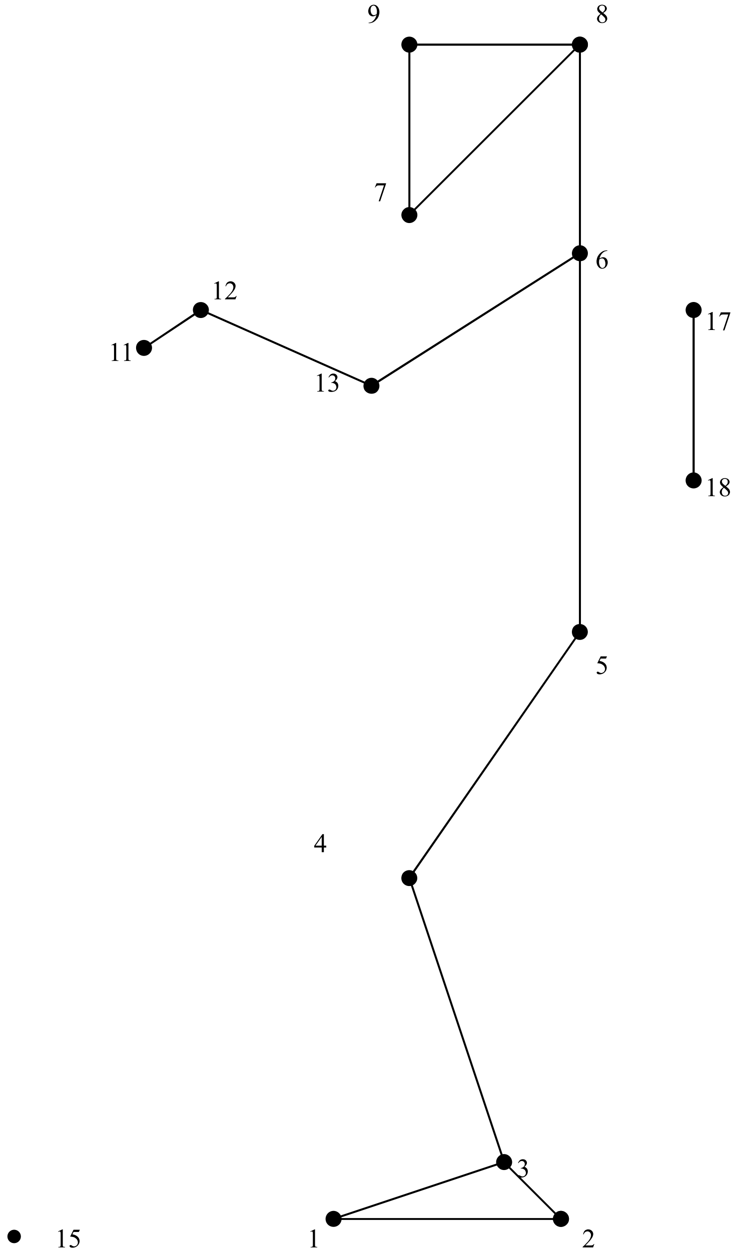

Fig. 7. Marker placement for jump analysis.

GLOSSARY

NET - Neuromuscular energising therapy.

CMJ - Counter-movement jump.

SJ - Squat or static jump.

EMG - Electromyography.

Co-ordination - The organisation of a systems multiple components.
The timing and sequencing of segmental movement.

Control - Scalar parameterisation of displacement, amplitude and speed.

Vertical Jump - The height attained using these methods has been defined as the difference between the height of the mass centre of the body at the apex of the jump and the height of this mass centre when the subject was standing upright with heels on the ground.

Equifinality - A single movement behaviour resulting from multiple muscle combinations.

Coda - Equipment for reproducing a three dimensional representation of jumping.

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