TOWARDS A PHYSIOLOGY OF THE F.M. ALEXANDER TECHNIQUE: a record of work in progress

by Christopher Stevens

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To

JoJo, Cody

Megan, Jessie and Ceri

and

your generations

With special thanks to

Nadia

Review

A long title for a short book, but necessarily so. It is a technical book and some of it is not easy reading for those unused to science. However it is of real relevance to Alexander Teachers.

The book begins with a statement of Alexander's discovery in modern physiological terms. Even here there is something new for many - the often forgotten importance Alexander placed on the legs, feet and arms. The book goes on to a short historical account of scientific interest in the Technique with quotations. It then briefly outlines earlier experimental studies into the Technique and the author's reasons for carrying out his research. There then follows an account of the author's experimental programme.

In this Chris is frank about the shortcomings of his own studies as well as the results obtained. This is important as good science is not getting the "right" answer but in asking questions, making practical experiments and then using all one's critical faculties to expose their errors so that new and better experiments can be carried out in the future.

This contrasts with the book learning approach, where a person can easily fall into thinking an idea "must be right". As Chris shows, things he (and we Alexander teachers) believed "must be right", can be wrong, just as Alexander did in his investigations.

This brings us to another important point: Chris carried out his experiments alongside his busy teaching practice and teacher training course. At the same time as he has been experimenting and reading the scientific literature, he has been facing the practical problems of Alexander teaching and to communicate Alexander's writings as well as his practical discoveries to private and training course students.

This triple set of demands has produced this book - and promises two others - one a commentary on Alexander's writings, the other a popular style account of the physiology and practice of the Technique to follow on from the earlier best seller "Alexander Technique", first published in 1987 and now in its eighth UK printing and with French, German, Hebrew and US editions also in print.

In the last section of "Towards a Physiology" Chris reviews a wide range of physiological research pertinent to the Technique. This section is in some ways the most interesting for non-scientists. It gives a broad overview of many interesting discoveries made by scientists over the past 20 years which are not commonly known by Alexander teachers and so forms a useful addition to our wider knowledge.

Finally, as Chris himself says, this is very much a record of work in progress, it is unfinished with new experiments still being analysed. Because of the dynamic progress being made a free update will be available to purchasers of the book in 1996, as well as a free question answering service on any points readers find difficult.

About the author

After graduating in Physics from the University of Reading, Chris taught physics for 5 years before doing post graduate study in Biophysics at Chelsea College, University of London. He began studying the Alexander Technique in 1969 and trained as a teacher under Walter Carrington.

He has been responsible for recognised Alexander teacher training courses since 1984 and is a member of both the British and German Societies of Teachers of the Alexander Technique. From 1988 to 1989 Chris was Chairman of the British Society of Teachers of the Alexander Technique.

He has carried out scientific research into the Technique since 1980 in the Department of Anatomy, University of Copenhagen and the Division of Basic Medical Sciences, Kings College, London. He is continuing this research with the Biomedical Engineering Group at the University of Surrey. It was through this research that he became interested in the study of postural and other reflexes and how they interact with the mechanics of the body and consciousness.

Through this Chris has continued Alexander's tradition of scientific method. By using modern scientific equipment and advances in scientific knowledge he has been able to improve his understanding and skills. This has led to new ways of teaching the Alexander Technique.

Some of Chris' other books and articles are:
Alexander Technique Optima, London 1987 re-printed 1988, 1989, 1990, 1991 2nd edition 1993 . Third enlarged edition to be published by Vermilion, London in 1996. There are also German (1989 and 1993), French (1989), Hebrew (1991) and American (1994) editions.

Alexander Technique: Medical and Physiological Aspects, (Ed) 1988, 1994.

Scientific Research and its Role in Teaching the Alexander Technique Alexander Memorial Lecture, STAT, London 1990

Alexander and Relativity, Alexander Review, 10 pages (English) 1990.

Research into the effects of the Alexander Technique STAT, London 1991, new edition 1994 also in German, 1944.

Yoga A and C Black, London, 1985, 1990, Third enlarged edition 1995

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Forward

This work is unfinished, as are all scientific studies. However a time comes where enough has been done to tentatively offer one's findings. But even as I write this experiments on balance and the initiation of walking are underway - who knows what these and subsequent work will produce?

The practical use of these studies

The experiments and literature study were aimed at deepening my understanding of the Technique and co-equally improving my own practice and teaching of it.

For example: with recording electrodes on my muscles when I was a subject in one of the experiments, the equipment detected unnoticed muscular activity to a degree which shocked me.

In other experiments the force platform data showed me equally unnoticed disturbances in my balance.

By means of experiences like these I was able to "calibrate" my sense of effort and balance even more precisely than I could with a teacher. This naturally helped me refine my practise and my teaching.

I was of course repeating Alexander's investigations into his behaviour using mirrors. Here though I could see in far finer detail what I was actually doing to myself when I thought I was doing something else.

From the literature studies I widened my knowledge of the neurophysiology of posture and movement. This informed my experiments and refined my questions. By incorporating these two aspects into my Alexander work I was able to further improve my methods and my ability to explain what I was doing, how to do it and why I was doing it.

For these reasons I hope that the book will be useful to practising teachers and students as well as scientists. As it is a rather technical report I offer a support service of replies to questions - for details see the end of this page.

Thanks to collaborators and helpers

This book is not only a lone effort. My thanks go to my research supervisor at King's College, Roger Soames; Michael Nielsen of Aarhus University; Flemming Gjedde, Rector of Aalborg Folk University; Finn Bojsen Møller, Copenhagen University; Nadia Kevan Folkwang Hochschule, Essen; Benjamin Libet, University of California SF; all of whom made significant inputs of help, resources, and corrections of some of my many errors.

Also to be thanked are Kathleen Ballard, Walter and Dilys Carrington, Paul Collins, Richard Kitney, Håkan Langshammer, Ruth Murray, Angela Thompson, TDM Roberts and Miriam Wohl who were instrumental in stimulating my investigations and for practical assistance with various aspects of a long process.

Naturally I remain responsible for the errors and omissions which remain.

Advice and Update Service

As stated earlier this is an unfinished work and I am still learning how to explain some of the fascinating discoveries being made.

To receive a free update of this book register yourself by writing to me c/o STAT giving the date and place of purchase of your copy.

To receive free advice and answers to your questions, send your queries to me c/o STAT with date and place of purchase of your copy.

Introduction

As a teacher of the Alexander Technique with a background in physics and physiology, I have been interested in studying the Technique from a scientific point of view. My aims were to understand it better by studying the work already done and add to this knowledge by measuring its effects with modern techniques. Together with co-workers, I have conducted experiments to measure and assess the changes produced by the Alexander Technique. I have also been interested in integrating relevant scientific knowledge to explain the results of the Alexander Technique found in the experiments. This combination of practical teaching experience, experimental studies and study of the literature has been attempted with a view to improving the teaching of the Technique.

I will begin with a short history of Alexander´s discovery and the development of scientific interest in his Technique. This is followed by a description of the experiments carried out by my collaborators and myself to date and the results obtained. These findings are then discussed in the light of some relevant current scientific concepts. From this I suggest some likely mechanisms for the changes observed.

Alexander´s Discovery

In the last decades of the 19th century, F.M. Alexander (1932) found, by observation of himself, that his vocal performance was adversely affected when he preceded his performance by making the following subconscious inappropriate postural preparations:
a) the production of excessive muscle tension through out the body, especially the legs and feet which caused:-
b) fixing the head in undue extension at the atlanto-occipital joint,
c) increasing his spinal curvatures,
d) undue shortening of the muscles of the legs and feet.

When he learned to inhibit these preparatory postural adjustments he found that his performance was improved. Through this experience he developed a method of teaching this conscious inhibition and choice to other people (now called the Alexander Technique). In addition to the improvement in vocal performance Alexander also found that his movement patterns, circulation, respiration and digestion were also improved. These findings have been confirmed by others and from 100 years of practical teaching experience.

Early scientific opinion

Some years after he arrived in England Alexander met Sir Charles Sherrington. At a personal level the meeting was not a success. However, Sherrington supported Alexander's work because he knew from his own laboratory studies, and from those of Magnus, that the neck and the head play a crucial part in the control of posture, balance and movement. Sherrington later wrote (Sherrington 1946):

> "Mr. Alexander has done a service to the subject (the physiology of posture and movement) by insistingly treating each act as involving the whole integrated individual, the whole psycho-physical man. To take a step is an affair, not of this or that limb solely, but of the total neuro-muscular activity of the moment - not least of the head and neck."

With the publication of Magnus' work in the 1910's and 20s, detailing the role of the head (eye and labyrinth) and neck and other postural reflexes, physiologists and doctors who recognised Alexander's work began to speculate about the mechanisms of his Technique. Meanwhile, the number of physicians and surgeons seeing the benefit of the Technique increased to the point where Bruce and 18 colleagues wrote to the British Medical Journal in 1937, urging that the Alexander Technique be included in medical training (Bruce et al. 1937). In it they said:

> "We have observed the beneficial changes.. brought about by Alexander's Technique in the patients we have sent to him for help. We are convinced that Alexander is justified in contending that an unsatisfactory manner of use... constitutes a predisposing cause of... disease... and that diagnosis... must remain incomplete unless a physician takes into consideration the influence of use upon functioning."

In 1941 Alexander worked with the biologist Coghill, who was so impressed that he wrote a foreword to Alexander's book, The Universal Constant in Living, in which he said (Coghill 1942):

> "Mr Alexander's method lays hold of the individual as a whole, as a self-vitalising agent. He reconditions and re-educates the reflex mechanisms and brings their habits into normal relation with the functioning of the organism as a whole. I regard his method as thoroughly scientific and educationally sound."

Shortly afterwards Dart began to take lessons. He quickly saw the importance of the Technique and later wrote (Dart 1970):

> "The electronic facilities (of electromyography and electroencephalography) have confirmed Alexander's insights and authenticated the Technique he discovered in the 1890's of teaching both average and skilled adult individuals to become aware of their wrong body use, how to eliminate handicaps and thus achieve better (i.e. increasingly skilled) use of themselves, both physically and mentally."

More recently Tinbergen made the following remarks in respect of the Alexander Technique in his Nobel Prize acceptance speech of 1974:

"We already notice, with growing amazement, very striking improvements in such diverse things as high blood pressure, breathing, depth of sleep, overall cheerfulness and mental alertness, resilience against outside pressures, and in such a refined skill as playing a musical instrument."

Experimental Studies

Until recently there has been relatively little published work on the effects of the Alexander Technique. In the following, I will discuss the pioneering work of Barlow, and of Jones and his colleagues, and more recent studies.

Dr Wilfred Barlow

During World War II, while in the army medical service, Barlow had begun to study young army recruits. These first experiments were extremely simple measuring the length of the neck when moving between standing and sitting. During the process of sitting there was an increase in the curve of the cervical spine, shortening of the distance between the occiput of the head and the vertebra prominens. All 56 subjects studied showed some shortening with 45 having a shortening of over 2.5 cm. Surprisingly only 3 of the subjects were aware of any change. When asked to focus on the shortening, only 12 subjects were aware of it. When asked to prevent it from happening, only 7 were able to do so. - Shortening of over 2.5 cm still occurred in 39 subjects even though they thought there had been no change.

Barlow's study clearly demonstrates Alexander's discovery of the inaccuracy of his own and others proprioception. It also reminds us that we cannot make improvements in our posture or movements just by "trying" when we suffer from unreliable proprioception. This is more fully discussed by Barlow (1947,1954,1955).

In a later study in 1956, Barlow had subjects adopt a standard upright standing position, using a method developed by Tanner (1962), and photographed them from the front, side and back. Analysing these photographs he was able to score their posture by using a grid system. He compared two groups of individuals before and after receiving training: one group received Alexander lessons and the other exercises aimed at improving posture. In the Alexander group there was a significant reduction in the number of postural faults following the lessons in both men and women while in the other group there was no significant change. The Alexander group were students at the Royal College of Music.

Their teachers reported the following on the Alexander students' progress: all the students improved physically both in their singing and acting abilities., whereby the rate of improvement varied greatly. They were easier to teach and had become more psychologically balanced. In addition, the success of the students in an important singing competition was far greater than could have been expected. In their opinion the Alexander Technique was the best method they had experienced for aiding singing performance and should form the basis of a singer's training.

In an attempt to determine whether fit young individuals have postural problems Barlow also measured 112 female physical education students. They also showed a large number of postural defects. The results for all three groups were independently assessed by Tanner.

The physical result of Alexander training is usually a more physiologically normal standing posture, from which it is evident that the body is more correctly aligned. Raine and Garlick (1986) have observed that the centre of balance of the body moves backwards following Alexander lessons, confirming Barlow's earlier findings.

Effects on performance

Barlow's work clearly shows the effect of the Technique on posture and on the level of performance. Evidence for improvements in health came from his clinical experience in medical practice (Barlow 1959,1964). Barlow's study with music students suggested a correlation between objective postural changes and performance. Jones (1972) also showed that not only did the singer and others listening feel that the voice and breathing were improved, but that there were measurable changes in the sound indicated by spectral analysis. More recently Doyle (1984) also observed objective improvements in violin players after Alexander training.

While considering improvements in performance the following experiences of two athletes are noteworthy. Paul Collins, Canadian National Marathon Champion 1949-52 and veterans world record holder in 10 events from 200 kilometres to 6 days has said (Collins 1987):

"Through the Alexander Technique I was able to rehabilitate my running after 25 years of being unable to run because of injuries, to the extent that I was able to set ten world records for veterans in 1982."

Howard Payne, Commonwealth record hammer thrower, improved his throw by 5.64 metres at the age of 37. Commenting on this, which he believed to be due primarily to taking Alexander lessons, he said (Payne 1967):

"Balance is a vital aspect of good hammer throwing and getting the head, neck, spine and pelvis in the correct relationship enables the balance of the throw to come so much more easily. Once the balance is settled there is an enormous improvement in turning speed."

Breathing

Barlow (1973) in his early studies found the Alexander Technique useful in dealing with breathing problems. Lung capacity and peak expiratory flow show a significant improvement after a course of Alexander lessons (Austin and Pullin 1984; Austin and Ausubel, 1992), while breathing is deeper and slower (Robinson and Garlick 1985).

Professor F P Jones

Jones used a different approach from Barlow preferring to measure muscle activity and movement patterns for unguided and guided movements. Straightening up from a slumped sitting position is usually associated with a sense of effort. When muscle activity is measured there is a high level of activity in the main neck muscles. However, when the habitual stiffening is prevented, the movement feels easier and the neck muscles show less activity. Jones suggested that this was due to the facilitation of appropriate head - neck reflexes (Jones 1965, 1979).

In 1960, Jones and Gilley used radiographs, to confirm that the Alexander movements produced an increase in the length of the sternomastoid muscles; these being key muscles in the control of head position and movement. Further examination of the radiographs showed that there was an increase in the thickness of the cervical discs in Alexander subjects and that there was also a forward movement of the centre of gravity of the head to a more physiologically normal position.

Jones later also used interrupted light photography to study the sit-to-stand movement. The photographs show a quicker and more direct movement following Alexander training.

The startle pattern has also been studied by Jones and Kennedy (1951). This is the typical reaction pattern of an individual when startled, for example, by a sudden unexpected noise. In this early study they found that the pattern always began in the neck and spread down the muscles of the body. Subjects typically retracted the head, raised the shoulders, flattened the chest, straightened the arms and bent the legs. In a later force platform study Jones (1979) found that in fact the legs initially straightened before going into the bent position.

It would seem from the casual observation of individuals that a form of the startle pattern becomes the norm as they get older: head balance is changed, with the neck shorter and pulled forwards while the head is pulled backwards relative to the neck, principally by the sternomastoid and trapezius muscles, with increased tension in the trunk and leg, just as these muscles tensed in the habitual movements discussed earlier.

The author's experimental programme

Two questions arise from the findings above. First, can the changes found by Alexander be measured reliably? And, if reliable measures of the changes can be made, what are the mechanisms responsible for these changes?

With respect to the first question, the early work of Barlow and of Jones and his colleagues suffer from the artificial nature of the test situations as

well as the possibility of introducing artefacts due to touching the subject. In addition the slow sampling rate (typically 10 Hz.) used by Jones in his experiments made calculation of velocities and accelerations from the displacement data unreliable (Lanshammer 1982). Using modern advances I was able to sample at 50 Hz. (studies 1 and 2) and 300 Hz in study 3.

As for the second question, Jones suggested in 1965 that the changes observed are due to a combination of the properties of bone, ligament, muscle and neck reflexes. His early account however does not include several current concepts including that of postural preparations. Another important mechanism currently under discussion is the possible role of the spinal curvatures. Recently Bojsen-Møller (1988) speaking on the likely mechanics of the Technique proposed the following view:

"I think a lot of low back pain, especially the acute, is actually a buckling which has been prevented by sudden heavy muscle contractions. There are several hundred kilograms of force in the muscles around the spine which can easily break the fibres of the muscle itself, tendons and the spinous and transverse processes - any of which can cause acute pain. So when I see you (teachers of the Alexander Technique) adjusting the vertebral column, I think of it in terms of you adjusting the vertebral bodies on each other and the ligaments of the back. By this you are changing the elastic stiffness of the system, the conditions for proprioception and the number of signals coming back to the central nervous system. Even though the changes are subtle they are causing a profound change in spinal function. The physiological effects and benefits could very well be large."

With these views in mind we conducted seven experiments to determine:
a) whether the Alexander Technique resulted in changes in task performance and/or physiological functioning, and
b) the nature of the underlying mechanisms, as follows.

A. Three experiments studying the sit to stand movement

1. An examination of the influence of leg position on the sit-to-stand movement. This enabled criteria for determining the quality of a movement to be developed, without requiring subjects to assume unusual positions.

2. An analysis of habitual and guided (in which preparatory postural adjustments were inhibited by a teacher of the Alexander Technique) sit-to-stand movement patterns. Force plate, electromyographic (EMG) and displacement data confirmed that guided movements required less muscle activity and less force to perform the movement and were also quicker. In addition the centre of balance was more posterior; with the subject being taller at the end of the guided movement.

3. A comparison of unguided movement patterns in an experienced practitioner of the Alexander Technique when using the Alexander Technique in the movement or when not. Using the criteria developed previously the Alexander movements were found to be more efficient than the non Alexander movements, using less force and taking less time.

B. Two experiments studying postural sway

4. The effect of neck and back splinting on postural stability when standing still was examined in untrained subjects to explore the relative importance of the neck, back and other postural reflexes. No significant effects were found.

5. A comparison of postural stability between subjects who had undergone Alexander training and those who had not. The Alexander group were no more stable with their eyes open or when their feet were in the normal position than the non-Alexander group, however their sway was up to 26% less when standing with the eyes closed and the feet together.

C. A study of height and shoulder width changes

6. The influence of Alexander lessons on static posture. Significant increases in both height and shoulder width were observed in musicians and office workers following Alexander training.

D. A study of stress related increase in blood pressure

7. An investigation into the effects of the Alexander Technique on circulatory parameters in professional musicians under the stress of performance. The Alexander Technique produced similar reductions in stress induced heightened blood pressure to beta blockers but without the adverse effects on quality of performance associated with the use of the latter.

I also examine and discuss possible mechanisms for the various changes observed. Further experiments on balance and walking are being undertaken and will be published in future reports.

Three experiments studying the sit to stand movement

Introduction

There is within any gross change of posture a process of postural adjustment which precedes and/or accompanies the voluntary movement (Belenkii, Gurfinkel and Paltsev 1967; Bouisset and Zattara 1981; Gahery and Massion 1981). Bouisset and Zattara (1981) have observed anticipatory movements present in the lower limbs and trunk before the beginning of voluntary arm movements. These movements, which contribute to the dynamic organisation of balance and serve to reduce the postural disturbance due to the forthcoming movement, are thought to be specific to the intended movement. If indeed this is the case then these postural adjustments must be pre-programmed, furthermore they appear to be organised at two levels (Gahery and Massion 1981). The lowest level provides for postural adjustment when the movement is triggered, this in turn being controlled by higher centres which adapt the adjustment to each intentional movement. This dual control system can be presumed to work during whole body movements as well as for single limb movements.

Jones and colleagues (Jones, Gray, Hanson and O'Connell 1959; Jones 1965) using kinematic and force platform data have attempted to analyse the postural adjustments preceding the sit-to-stand manoeuvre. He has shown that objective measures can be used to distinguish between well and badly co-ordinated movements (Jones and Hanson 1961; Jones, Hanson, Miller and Bossom 1963), and thus lead to a clinical diagnosis of abnormal patterns of movements. More recent studies of the sit-to-stand manoeuvre have typically used standard leg positions (Baid, Kralj and Turk 1982; Christiansen, Kardorf and Bojsen-Møller 1982; Yoshida, Iwakura and Inoue 1983). However, as this may not correspond to the normal position of the subject, the subsequent movement may not be typical. If, as suggested earlier, the pattern of postural adjustments is movement specific, then the execution of the movement will be influenced by the initial posture.

The sit-to-stand movement is universal, easy to analyse and changes very little on repetition (Jones and Hanson 1961,1962). It is therefore useful for studying the effects of postural preparations. To this end we used the analysis of this movement in two experimental programmes to investigate the influence of initial posture with respect to leg position on the magnitude and pattern of postural adjustments and on the total movement pattern. In addition, the inhibition of postural adjustments of the head was examined with respect to the execution of the movement.

Experiments 1 and 2: A two dimensional analysis

Methods

We examined the sit-to-stand movement using photographs, a force plate and electromyography (EMG). During the sit-to-stand manoeuvre the trajectories of the head, shoulder, pelvis and knee were recorded, as well as the three orthogonal ground reaction forces and the electromyographic activity of selected muscles. Two male subjects took part in the study, a total of 64 movements were recorded and analysed. Details of the methods employed can be found in Stevens, Bojsen-Møller and Soames (1989).

Experiment 1: Influence of leg position

Results

Major differences were seen in the patterns of body movement, particularly of the head, as well as of the ground reaction forces between standing from the seated posture with the legs in a standard position (thighs horizontal and calves vertical), or the individuals preferred position ($P< 0.01$ in both cases).

Compare the head trajectories in figures 1a and 1b. The head moved 18% less in the horizontal plane and 35% in the vertical plane. The force platform records showed corresponding reductions between the two patterns; a 24% reduction in the preparatory reduction in vertical force, F_z, as the subject prepares to stand, and a 70% reduction in the horizontal forward force, F_y, in the same phase of the movement.

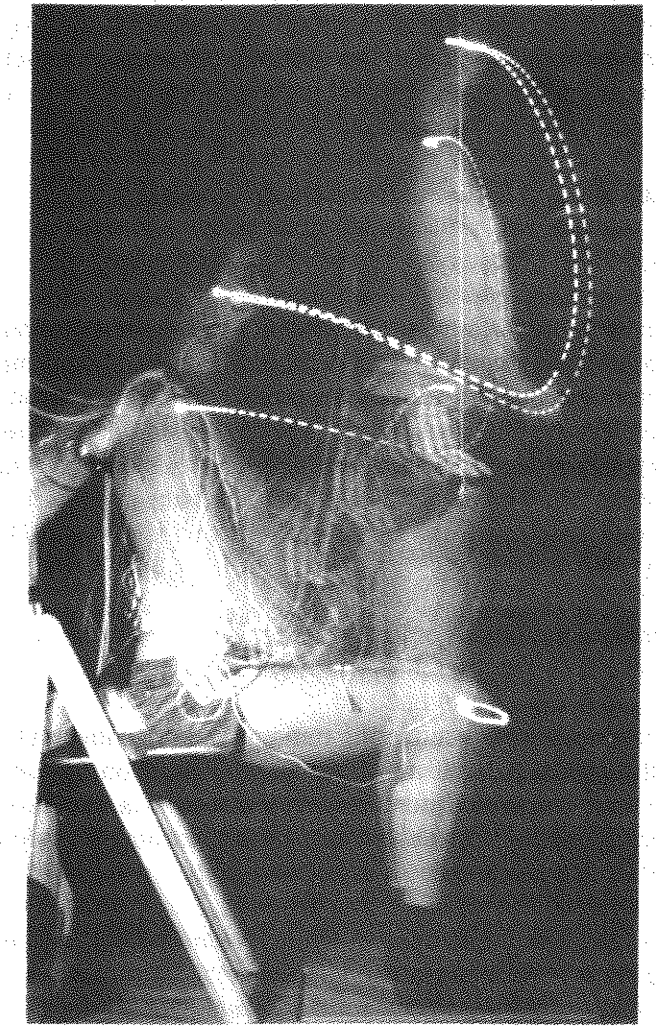

Figure 1a . Sit to stand with legs at 90 degrees

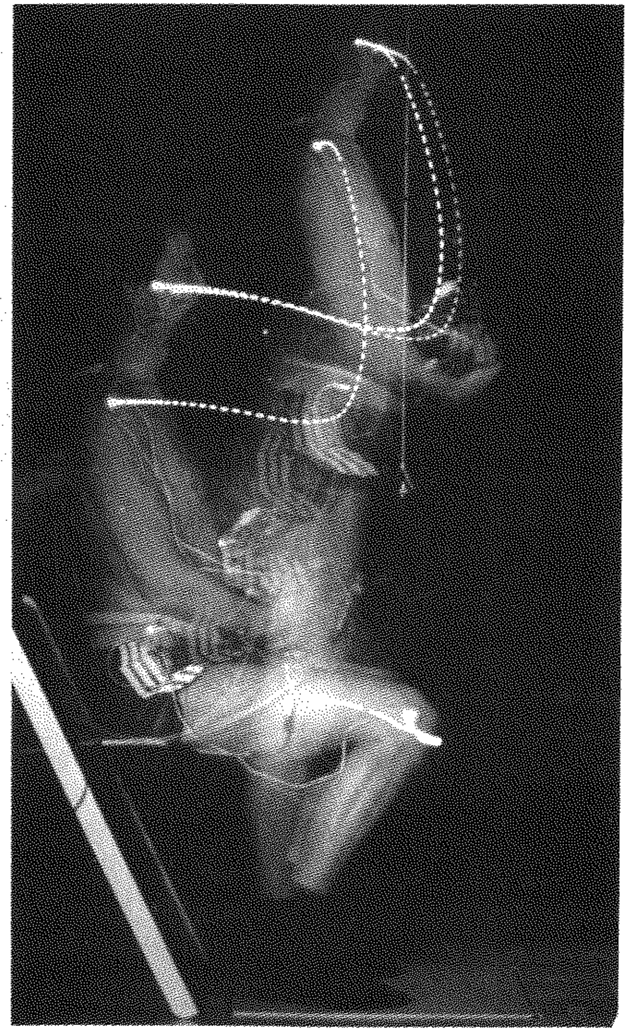

Figure 1b . Sit to stand with legs in the preferred position

It appears that with the standard leg position there is a higher level of activity in the upper trapezius and erector spinae muscles compared with that seen with the preferred leg position (records not shown in this report). These differences in muscle activity correlate with the differences seen in head movement and upper trunk movement between the two test conditions. In contrast greater activity was generally observed in the hamstring and quadriceps muscles in the preferred leg position trials. This correlates with the greater knee movement seen in figure 1b compared with 1a.

Experiment 2: Guided and unguided movements

Results

To prevent an unnatural initial posture which places additional demands upon subjects, each subject was allowed his own preferred leg position in the guided and unguided movement studies. Head movements, vertical force records and EMG activity all showed major differences between the guided and unguided movements ($P < 0.01$ in all cases). In the guided movement the descent of the head was reduced by 43% and the horizontal head movement by 16%. The preparatory dip in the vertical force record and the maximum force were also reduced by 77% and 16% respectively (not shown in this report). EMG activity in upper trapezius, sternomastoid and erector spinae also showed reductions of 53%, 38% and 19% respectively.

Examples of the movement patterns are shown in Figures 2a and 2b for the unguided and guided movements respectively. In Figure 2a it can be seen that there is a postural adjustment consisting of an extension of the head during the early part of the movement. This postural adjustment has been prevented in the guided movement (Figure 2b).

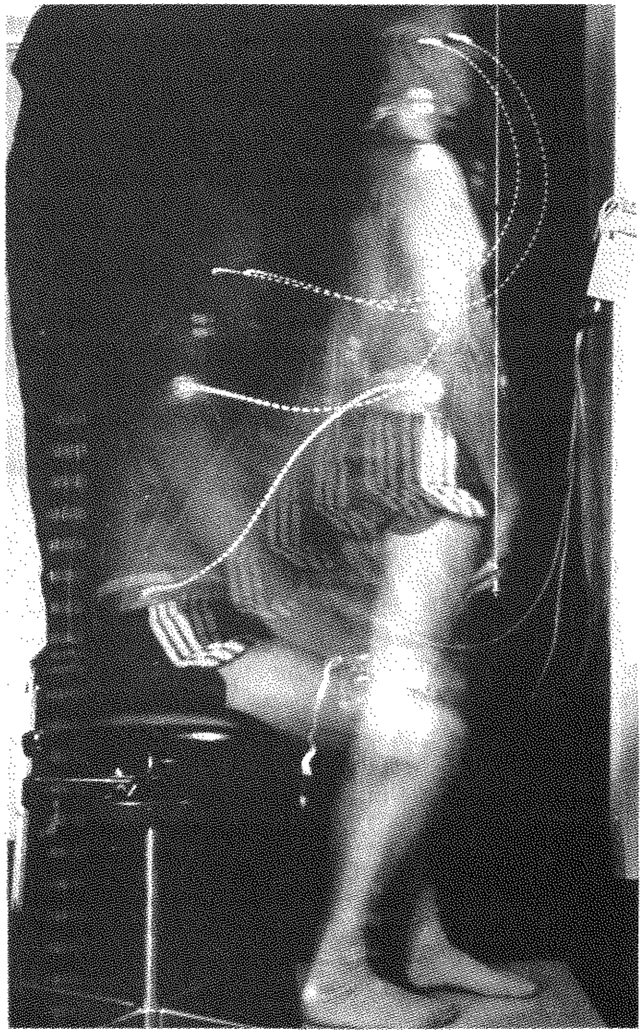

Figure 2a. Sit to stand without guidance

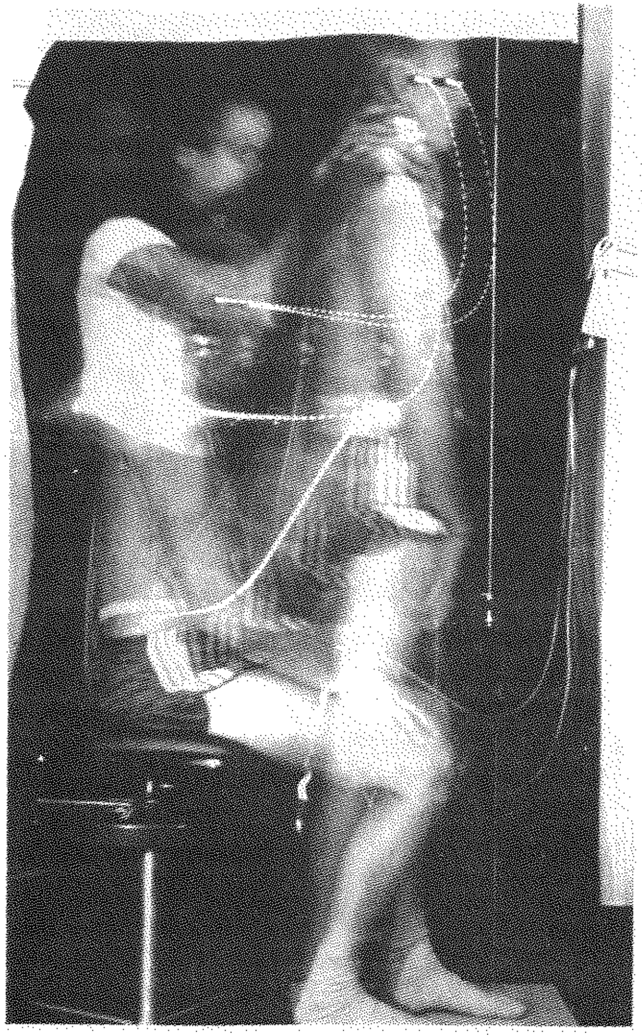

Figure 2b. Sit to stand with guidance

Discussion of experiments 1 and 2

The data (see Stevens et al 1989 for further details) suggest that both initial leg posture and the abolition of habitual postural adjustments of the head have a profound influence on the pattern of the sit-to-stand movement. It can be argued that because of the different preferred leg positions adopted by subjects, that data relating to this factor may be misleading. Alternatively it can be argued that given differences in body size, strength, handedness, eye dominance and general fitness, individuals through experience will adopt a preferred leg position which they find the most effective and efficient for them.

Using the latter argument all preferred leg positions could be considered to be comparable. Imposing a standard, non-preferred leg posture will place additional demands upon subjects when the movement is performed because the initial posture is non habitual. The increased muscular activity and a greater head movement seen in trials with a standard initial leg posture supports this latter view. At the beginning of the movement the weight of the body is brought forward over the base of support, that is the feet. Therefore the further forward the feet are placed then the greater the forward movement of the head and trunk will be. The additional effort required in producing this movement may reset the thresholds of habitual postural adjustment so that these adjustments become more pronounced. Any resetting is most likely to be related to changes in neck posture when leaning forwards.

The suggestion that reflex thresholds are reset is supported by the findings from the guided and unguided trials. By inhibiting head movements (guided trials), and therefore changes in neck posture, the pattern of movement appears to be smoother with associated muscle activity reduced.

It has long been known that the neck musculature is important in the control of posture and movement. Longet (1845) showed that surgical interference with the neck muscles produced generalised disturbances in posture and movement in a wide range of animals. Sherrington (1897) later established that neck receptors have a profound effect on head posture.

Building on this earlier work Magnus (1924) was able to show that neck afferents, particularly in association with labyrinthine reflexes, can produce extensive changes in whole body posture. More recently it has been suggested that the neck receptor system may be just as important as the labyrinthine system for the control of posture (Lindsay, Roberts and Rosenburg 1976). Cervical ataxia has been produced in many species, including man (Cohen 1961; de Jong, de Jong and Cohen 1977; Lund 1980); the effects, however, are not thought to be due to loss of motor control of the head but to a more generalised disorder (de Jong et al. 1977).

The precise location of the receptors responsible for controlling head position is the subject of much discussion. McCouch, Deering and Ling (1951) and Wyke (1979) believe them to be located in the cervical vertebral joints, but their studies have been criticised by Abrahams (1982) and Richmond and Bakker (1982). Others have stressed the importance of the neck muscles (Cooper and Daniel 1963; Abrahams 1977). Indeed the numbers and arrangements of the spindles in these muscles is impressive. For example in the cat the number of spindles per gram range from 100 for large to 500 for small neck muscles (Bakker and Richmond 1982); in comparison lateral gastrocnemius only contains five spindles per gram (Bakker and Richmond 1982).

It is interesting to note that the muscle spindles in the neck are arranged in complexes (Richmond and Abrahams 1975) suggesting that they may sub serve special functions. Furthermore, afferents leaving the neck muscles have profound effects on hind limb motor neurone excitability (Abrahams and Falchetto 1969). This latter observation, although not made on humans, may be a possible explanation of the lack of preparatory leg retraction observed in the guided trials in the present study.

Conclusions

Preferred initial leg postures produced less head movement and ground reaction forces. In addition the EMG activity in some muscles (trapezius and erector spinae) was less, while in others (quadriceps and hamstrings) it was greater in the movement from the preferred leg posture. The decreases in head and trunk EMG activity correlate with observed reductions in head movement. Guided movements, in which habitual postural adjustments of the head and neck are inhibited, showed significant reductions in head movement, ground reaction forces and EMG activity in trapezius, sternomastoid and erector spinae. It would appear therefore that both initial leg posture and the abolition of habitual postural adjustment have a profound influence of the efficiency of the sit-to-stand manoeuvre.

This study draws attention to the practical importance of head posture in the diagnosis and treatment of movement disorders, as well as in movement education. It was first published in the European Journal of Applied Physiology, under the title 'Influence of initial posture on the sit-to-stand movement'. (Stevens, Bojsen-Møller and Soames, 1989)

Experiment 3. A three dimensional movement analysis

In the last study, habitual postural preparations of the head were restricted by guiding the head. It is possible that this may have introduced artefacts into the study due to touch, although every attempt was made to minimise this. Also the reliable calculation of velocities and accelerations from photographs is difficult if the movement is slow because of the superimposition of the images and analysis of the movement is restricted to two dimensions.

To overcome these problems the following were used in a pilot study of a further series of sit-to-stand trials:
(i) a trained practitioner of the Alexander Technique, who was able to voluntarily inhibit his postural preparations (corresponding to guided movements),
(ii) an electronic 3-dimensional movement analysis system, and
(iii) a force platform and strain gauge seat,

The trained practitioner of the Alexander Technique used the following three movement strategies in both the three-dimensional analysis and the force platform studies:

1. Moving with no thought of how he was moving (Strategy 1).
2. Consciously making an effort to move quickly (Strategy 2).
3. Applying the Alexander Technique to the movement (Strategy 3).

Results

1. Head displacement

The differences between these approaches is shown in the trajectories in Figure 3a (strategy 1), Figure 3b (strategy 2), Figure 3c (strategy 3).

The vertical and horizontal movements of the head were used as indicators of the overall pattern of movement. The results obtained from the trajectory traces show a reduction of up to 60% for the vertical movement, and up to 57% of the horizontal movement of the head.

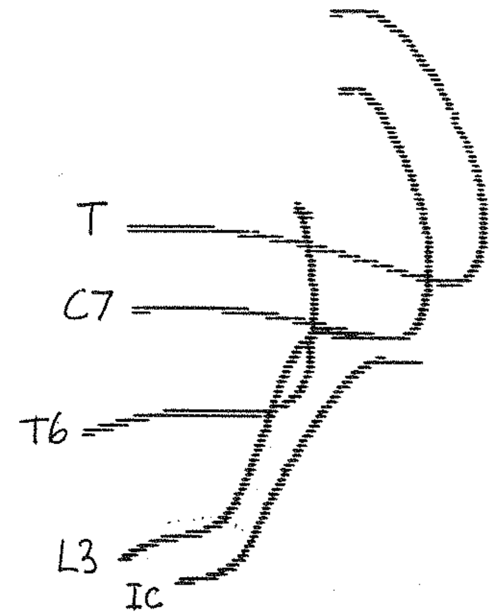

Figure 3a. Sit to stand moving with no thought of how he was moving (Strategy 1). (T = tragion of left ear; C7 = spinal process of seventh cervical vertebra; T6 = spinal process of sixth thoracic vertebra; L3 = belly of erector spinae at level of third lumbar vertebra; IC = apex of iliac crest)

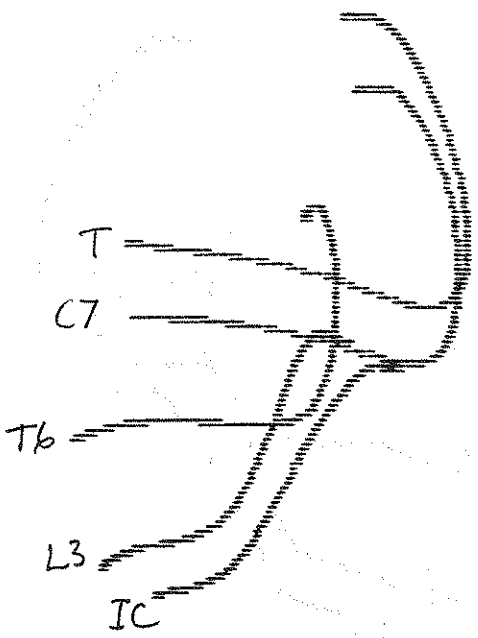

Figure 3b. Sit to stand consciously making an effort to move quickly (Strategy 2). (T = tragion of left ear; C7 = spinal process of seventh cervical vertebra; T6 = spinal process of sixth thoracic vertebra; L3 = belly of erector spinae at level of third lumbar vertebra; IC = apex of iliac crest)

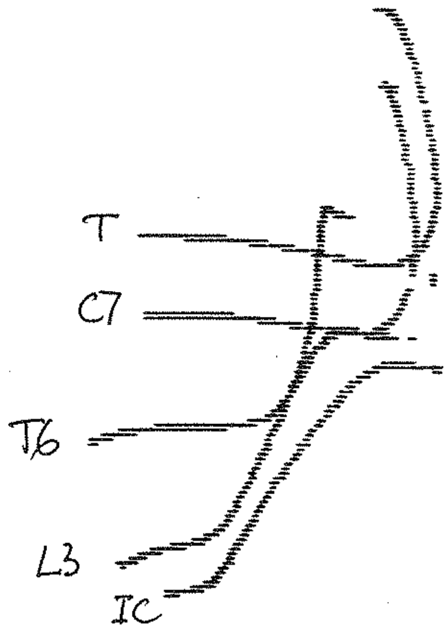

Figure 3c. Sit to stand applying the Alexander Technique to the movement (Strategy 3). (T = tragion of left ear; C7 = spinal process of seventh cervical vertebra; T6 = spinal process of sixth thoracic vertebra; L3 = belly of erector spinae at level of third lumbar vertebra; IC = apex of iliac crest)

2. Head velocities

Figure 4 shows the horizontal anteroposterior and figure 5 the vertical velocities of the head under the 3 strategies.

By using a high data sampling rate (300 Hz) and measuring to an accuracy of less than 1 mm, it is possible to make reliable velocity calculations from the displacement data (Lanshammer 1982). These calculations show that only the upward vertical velocity is higher in the Alexander movement (9-31%); in the downward vertical, anterior and posterior directions the velocities were less (by up to 35%, 16% and 45% respectively). The movement traces also show that the movement takes less time (5-22%).

3. Force platform studies

Figure 6 shows the vertical force records on the seat and feet for a sit-to-stand without thought trials (strategy 1). Figure 7 shows these forces when making a conscious effort to stand up as quickly as possible (strategy 2). (In this test the subject walked off the platform). Figure 8 shows the effects of using the Alexander Technique (strategy 3).

The following measurements were taken from Figures 6 - 8:
maximum force increase on the seat (S),
maximum force decrease at the feet (F),
Peak force above body weight (P).

Measurements of the time taken for the feet to take full body weight showed no significant differences between the various conditions.

The preliminary increase in seat force shown in strategy 1 (Fig. 6) is virtually absent in strategy 3 (Fig. 8) as is the corresponding preliminary reduction in foot force (reductions of 69-87%). Similarly the peak force required for the movement is reduced by 22 to 23% in strategy 3.

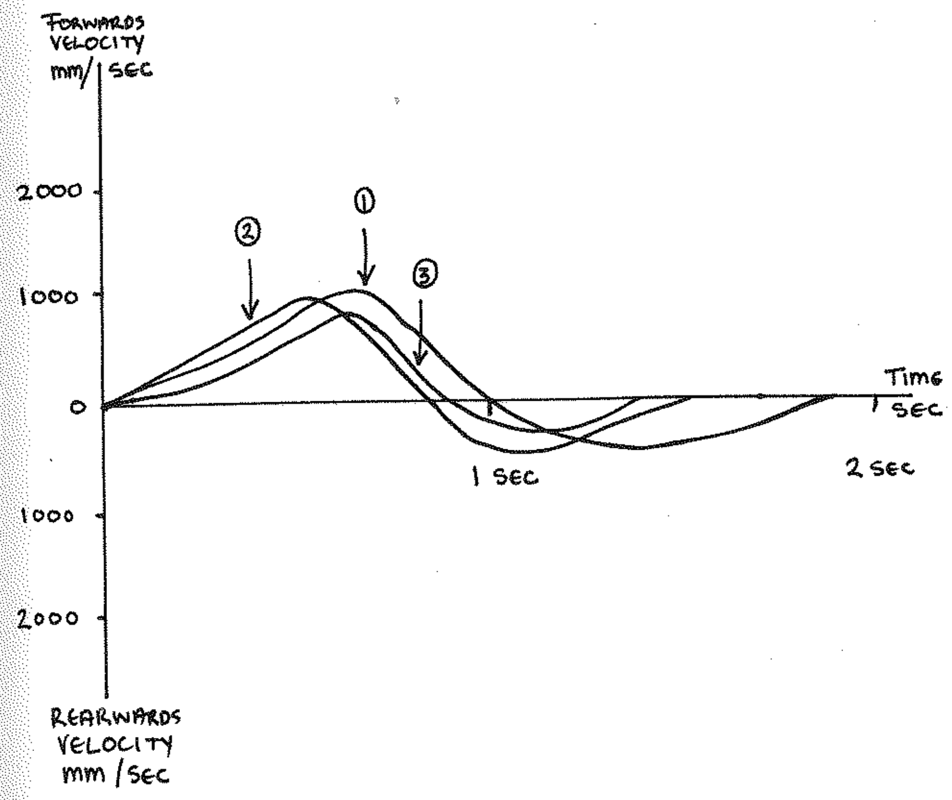

Figure 4. Horizontal anteroposterior velocities of the head under the 3 strategies.

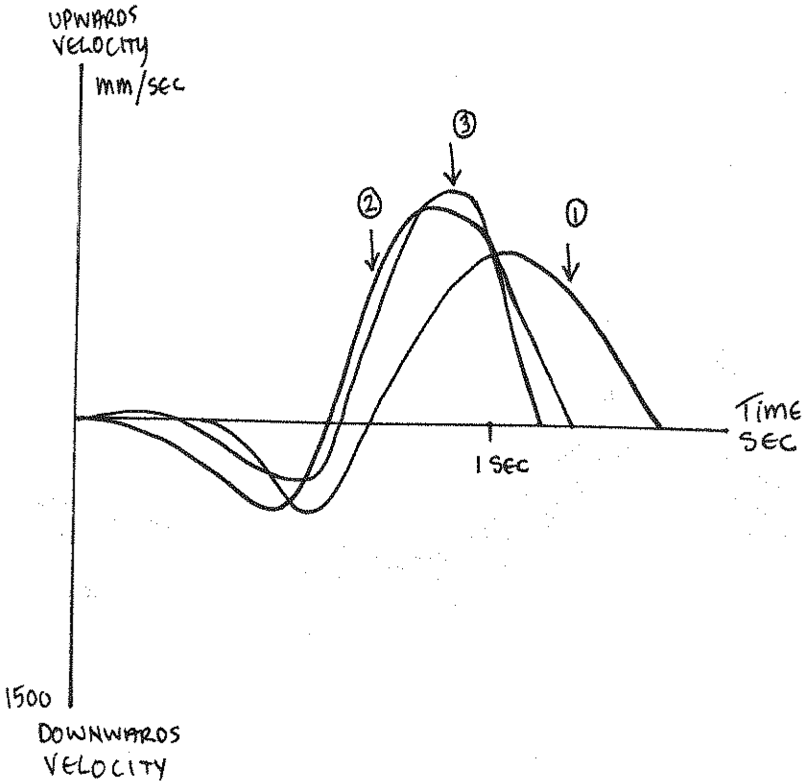

Figure 5. Vertical velocities of the head under the 3 strategies.

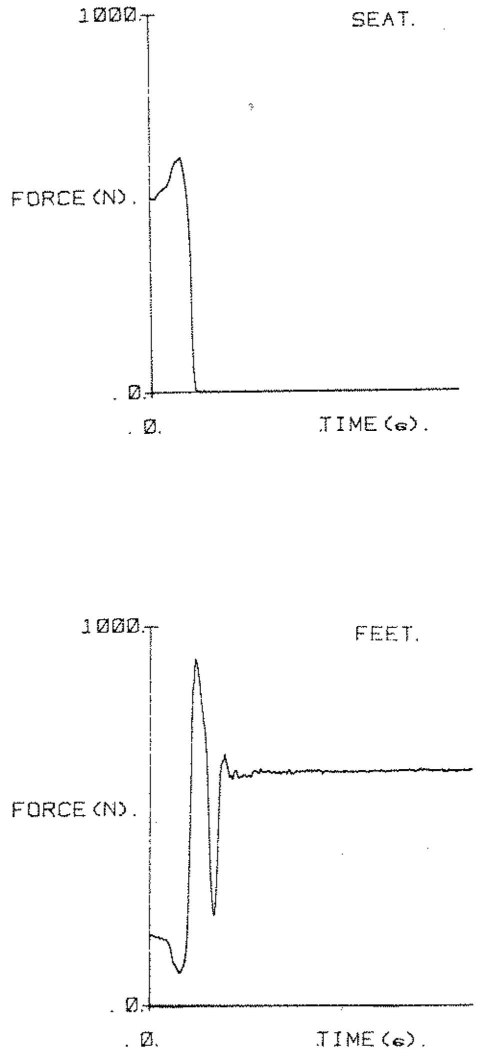

Figure 6. Vertical forces from the seat and feet in strategy 1

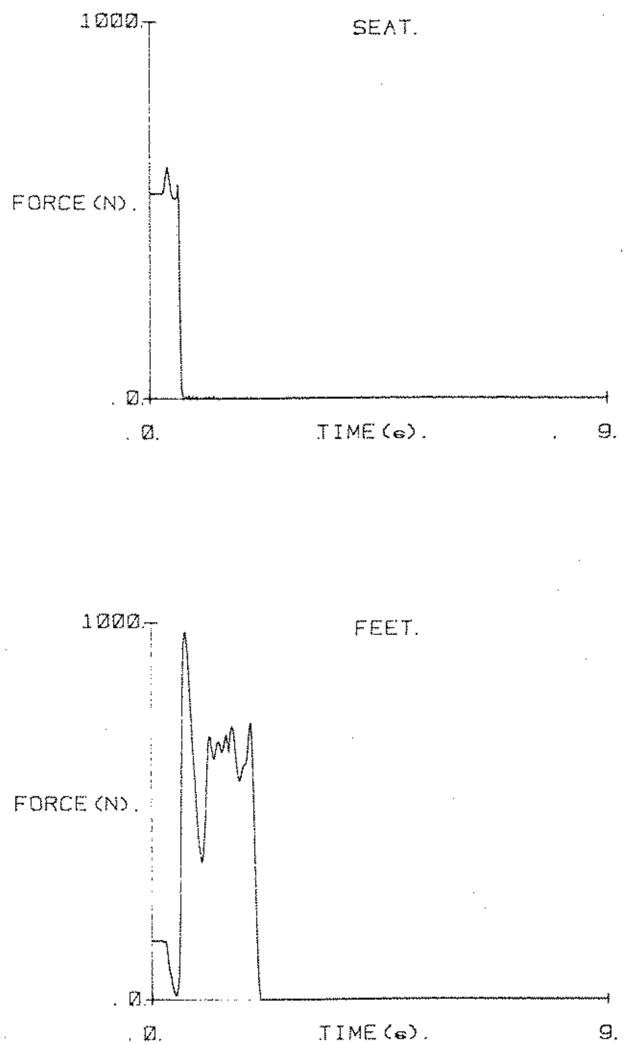

Figure 7. Vertical forces from the seat and feet in strategy 2

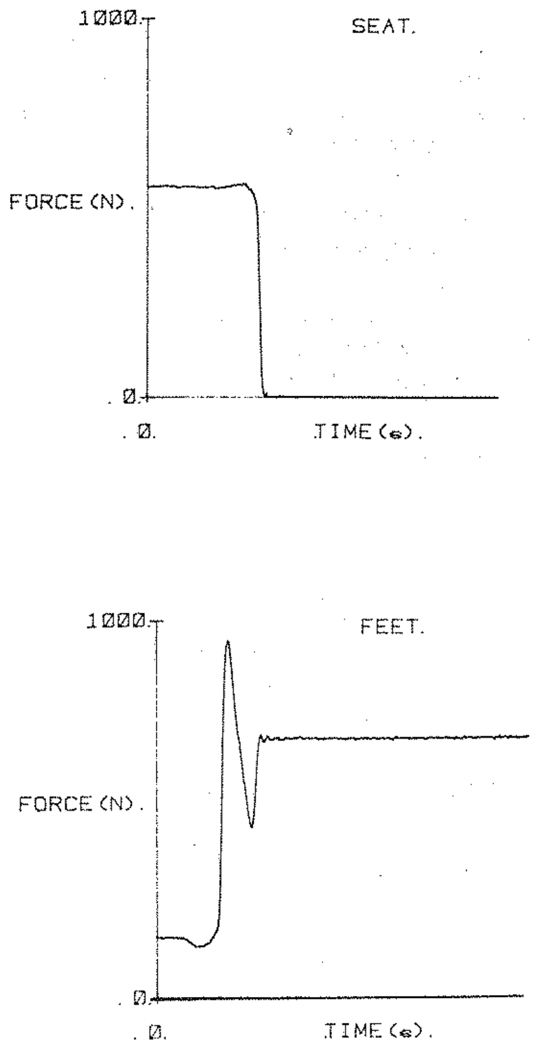

Figure 8. Vertical forces from the seat and feet in strategy 3

Discussion

The study was performed on one subject . In total 12 trials were recorded and analysed. Naturally studies of many more subjects and trials are needed for a statistical analysis. However the study does show that measurements can be made and that an experienced practitioner can make measurable changes to their movement patterns.

Also it is in agreement with the findings of Jones and Hansen (1970) in their force platform studies of unguided and guided movements, which showed a preparatory reduction in vertical foot force, and with those of Jones et al. (1959) who analysed 92 sit-to-stand trajectories, using multiple image photography, produced by 6 subjects before and after taking 20 Alexander lessons. The above results also suggest that there are long term effects as well, because an experienced practitioner can chose to use the Alexander Technique at will.

Conclusions

In both the trajectory and force platform studies the differences between the various movement strategies is clearly observable. Though, as indicated, confirmation is needed, the apparent improvements in the efficiency of the movement using the Alexander Technique, without changes in the starting position of the movement, suggest that postural and other movement mechanisms are being utilised in a more effective way.

Postural studies

Introduction

Postural stabilisation appears to be a continuous dynamic process of corrections based on inputs from the visual, vestibular, somatosensory and auditory systems. The magnitude of sway increases if the eyes are closed, or the subject is blindfolded (Lee and Aronson 1974) and postural control deteriorates (Hlavacka and Krizkova 1979).

Vestibular deficiency causes marked changes in the individuals references to gravity (Black, Wall and Nashner 1983), while ipsilateral labyrinthine loss causes increased lateral sway (Tokita, Maeda and Miuata 1981).
Proprioceptive information from the joints of the ankle and foot and their associated muscles, as well as the skin on the soles of the feet are important in maintaining balance, as shown by Heyd (1862, quoted by Harris 1938 in Orma 1957). Orma (1957) also observed increased postural sway in women, but not men, when standing with their feet immersed in ice water.

The contribution to postural stability of the auditory system is more recent and more tentative. Era and Heikkinen (1985) found evidence of poor postural control amongst subjects who had been exposed to noise at work.

Head position is signalled by two interacting sources: firstly by the primary vestibular afferents, providing information about head position and movement, and secondly by the proprioceptors of the limbs, trunk and neck, giving information about head position relative to the rest of the body. This enables a different and appropriate response to changes in head position due only to head movements (such as shaking the head) and changes in head position due to movement of the whole body (Lund and Broberg 1983).

Animal studies have clearly shown the interactions of head and neck reflexes in quadrupeds (Roberts, 1973). In addition Lund and Broberg

(1983) have shown in humans that the position of the head relative to the trunk, and the position of the trunk relative to the legs, affects the postural sway responses to an electrical stimulus to the vestibular system. Priest (1984) has shown that when wearing a neck splint, balance on a beam was markedly impaired for a gymnast who normally had good balance ability on such equipment.

Postural sway studies were conducted to determine whether the Alexander Technique improves balance, as shown by a reduction in postural sway behaviour, and to assess whether neck and back proprioceptors are important in this. To do this the effects of neck and back splinting on postural sway in normal subjects was examined and sway behaviour between normal and Alexander trained subjects compared.

Experiment 4: The Effects of Neck and Back Splinting on Postural Sway Behaviour

Methods

A force platform and relevant software were used to detect and analyse six measures of postural sway. These were mean lateral sway (Xm), mean antero-posterior sway (Ym), mean displacement of the centre of pressure (Rm) and three others.

For each parameter a three-way analysis of variance was conducted to determine the effects on sway behaviour of :

- the two types of splinting, singly or together,
- the feet being together or in their preferred position,
- and whether the person had vision or was blindfolded.

26 subjects, 13 male and 13 female took part in the study. Each took part in 16 experimental conditions. In all 416 experiments were recorded and analysed.

Results

Not surprisingly sway was greater when standing with the eyes closed than with the eyes open, and for the Romberg (feet together) foot position compared to the preferred position .
Females exhibited less lateral sway than males.
There was no significant effect of the various splint conditions in either males or females.

Discussion

The lack of significant changes in sway behaviour in relation to splinting was surprising, as it was expected that reduced information from the neck proprioceptors in particular would lead to deficiencies in postural control. One explanation for this may be that the centre of pressure movements, as recorded in the study, are perhaps an insensitive measure of postural sway. This may be due to the lower body compensating for changes in the head and neck or vice versa without any change in the position of the centre of pressure. A combination of instruments as used in the previous experiment would clarify this.

However, it is possible that the trunk and neck proprioceptors are not needed in quiet standing, only being called into action during movement or at the extremes of normal balance. In this regard Orma's (1957) report on the importance of ankle and foot proprioception and Lund and Broberg's (1983) suggestion of a role for the knee and hip, would provide alternative sources of stabilisation.

One could argue that the splints used may not have been sufficient to prevent small changes in the relative positions of the various body segments, particularly the trunk splint. However, simple manual tests indicated that the neck and trunk were indeed immobilised.

The literature on the differences in sway between men and women is contradictory, with some authors reporting greater sway in women (Orma 1957; Overstall, Exton-Smith, Imms and Johnson,1977). Soames and Atha (1978), however, report that males tend to sway less in the anteroposterior direction and more in the lateral direction than females. These differences in results may merely reflect the various measurement techniques and postures adopted, especially foot position conditions. In my study males had a wider preferred foot position with a greater degree of out turning than the females. Consequently changes in the area of the base of support between the preferred and Romberg foot positions is proportionally greater in the males.

Conclusions

Splinting of the neck and/or back was found to have no significant effect on postural sway behaviour. As observed in previous studies closing the eyes and standing with the feet together (Romberg position) leads to increases in postural sway, with females tending to sway less in the lateral direction than males. This may be due to the wider base of support when standing in the preferred foot position in males than in the females, although the difference did not reach significance in t-tests.

Experiment 5: A comparison of the sway behaviour in normal subjects and experienced Alexander students

It has been suggested that the Alexander Technique improves both movement patterns and their co-ordination (Jones, 1979). These changes are probably due to an improved awareness of the relation between various body parts, with greater importance given to proprioceptive feedback than in untrained individuals. If this is indeed the case then students training to be teachers of the Alexander Technique should show different sway characteristics when standing compared with untrained subjects.

An initial group of 6 such students each were recorded under 4 conditions for a total of 24 sessions were recorded and analysed. These were compared with the same conditions for the untrained group. Splinting was not attempted for this group.

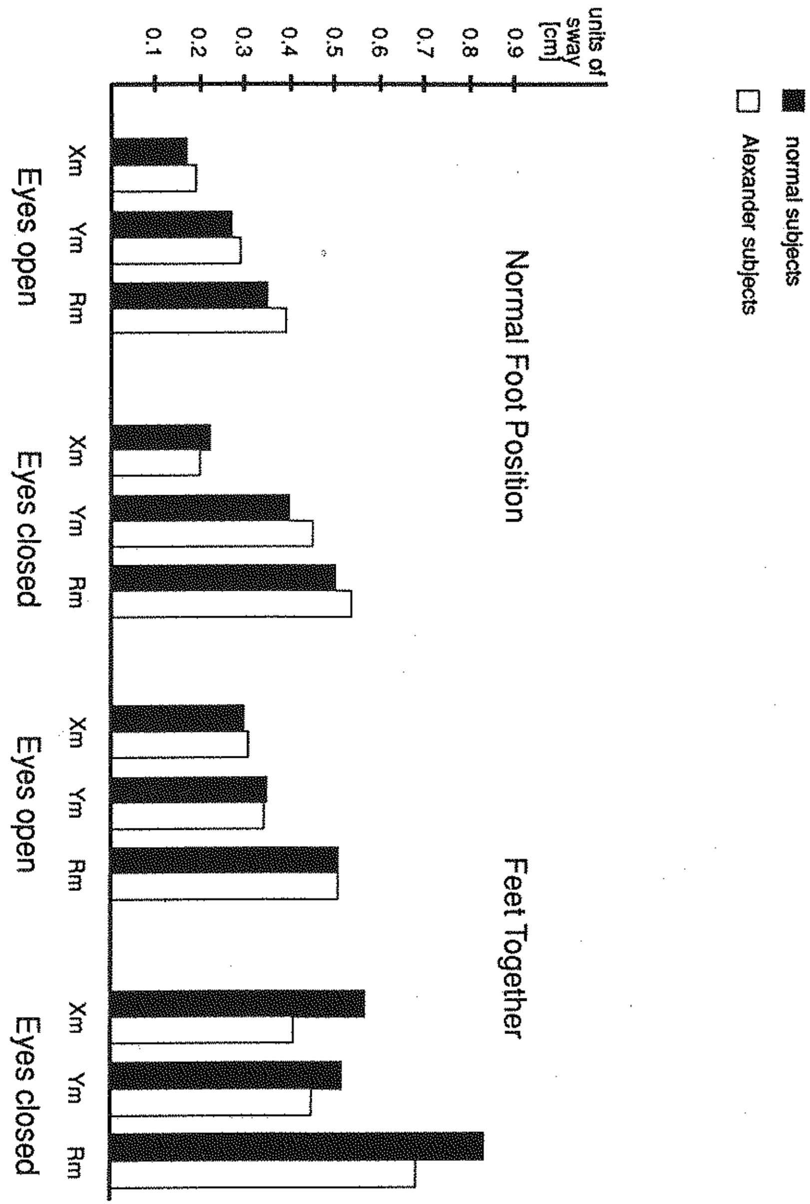

Figure 9. Differences in sway between untrained subjects (solid histograms) and Alexander trained subjects (open histograms)

Results

The means of the sway measures are presented in Figure 9. The only significant difference between the normal and the Alexander trained subjects is when standing with the eyes closed and the feet together. Statistical tests showed that the other differences were non significant. The reduction in sway exhibited by the Alexander group as compared to the normals was 26% laterally, 14% anteroposteriorly and 16% in the mean displacement of the centre of pressure.

Discussion

The lack of difference in sway behaviour between the two groups when standing with eyes open is not surprising given that vision is the most dominant of all feedback mechanisms in postural control. When standing with the feet in the preferred position subjects would presumably ensure that they feel comfortable and have a relatively large area of support. It is only when deprived of vision and with the feet together that differences between the two groups are seen, that is in the least favourable posture.

This suggests that the differences observed here were due to the awareness and use of proprioceptive information. Odenrick and Sandstedt (1984) have shown that proprioception is of utmost importance when standing with the eyes closed. According to Harris (1938), quoted in Orma (1957), Heyd (1862) was the first to stress the importance of proprioceptive feedback from the ankle and foot.

Alternatively Lund and Broberg (1983) believe that it is information from the knee and hip which provide the basis of proprioceptive postural control. It is unlikely that the vestibular system is involved as it is less sensitive to fine body movements (Lee and Aronson 1974) than other systems.

The observed changes are also unlikely to be the result of practice. Firstly none of the subjects had learned to try to stand still and although training in the Alexander Technique is concerned with balance, this is achieved by greater attention to body processes. Conversely, Fearing

(1924) showed that sway magnitude could be reduced by training but found that it was accompanied by a change of direction in the subjects attention from being conscious of body processes to a more externalised attitude. Furthermore none of the Alexander subjects had ever attempted to reduce their postural sway, nor were they asked to do so in the experiment.

The foot position measurements underline the better balance of these subjects compared to the untrained group as their preferred foot position is significantly wider than normal males and thus the difference in the area of support between the preferred and the Romberg position is greater.

In the elderly, postural sway is a predictor of the propensity to falls (Clark, Lord and Webster, 1993). Thus methods for reducing sway may be helpful in reducing the danger of injury due to falling in the elderly.

Conclusions

The significant reductions in sway behaviour observed when standing in the Romberg position suggests that the Alexander trained subjects were able to make better use of proprioceptive information, probably mainly from the hip, knee, ankle and foot, than normal subjects. Alexander trained individuals therefore seem to have a greater awareness of their body posture and the relation of one body part to another. The improvements observed in balance are in line with the reports of other investigators (Jones 1979; Barlow 1973).

Trials with larger groups of male and female Alexander and untrained subjects are underway to investigate these differences further.

Experiment 6: Height and shoulder width before and after Alexander lessons

Measurements of posture made by Barlow (1956) concentrated on the scoring of faults. He later claimed (Barlow 1973) that there had been increases in height and shoulder width following Alexander training. If muscles lengthen due to Alexander training, then a simultaneous increase in both height and shoulder width are to be expected. Michael Nielsen, Birgitte Due and I examined whether these changed following Alexander lessons.

Methods

The height and biacromial width of 20 subjects was measured at the same time of day before and after a short course of Alexander lessons, using standard anthropometric instrumentation.

To eliminate changes due to illness, medications or psychological state, measurements were not made when subjects had taken any kind of medication, had coffee, tea or alcohol, or did not feel well in any respect, during the 3 hours prior to the measurement session.

Results

The subjects showed significant increases($P < 0.01$ or 0.05) in standing and sitting height and in biacromial width following Alexander lessons. Students who received an average of 11 lessons over 3 months showed a mean height increase of 7 mm and a mean increase in biacromial width of 15.8 mm. The other group that received 20 lessons over 7 months showed a mean height increase of 10.2 mm and a mean increase in biacromial width of 12.5 mm. In general the females showed greater increases in height, while the males showed greater increases in biacromial width.

Discussion

There was no control group in this study and there appears to be no published data on height changes over such short periods of time in otherwise normal individuals, except during childhood. Diurnal variations are to be expected, however this was taken into account by taking all mea-

surements for each subject at the same time of day. The mean diurnal variation has been reported to be 16 mm (De Puky 1935).

Conclusions

The number of lessons given to the subjects was considerably less than the number recommended by Alexander (1932) (30) or Barlow (1956) (40), with some subjects receiving as few as 5 lessons. However significant changes in height and shoulder width can be seen after only a few lessons. A longer term follow up study with more subjects is indicated.

The mechanisms for the changes observed are likely to be related to the releasing of excessive muscle tension and unbalanced postural habits, which allow the reduction in excessive spinal curvatures as noted by Alexander (1932) and Barlow (1955). The increase in shoulder width, also noted by Barlow (1973) is likely to be due to the releasing of the muscles attaching to the pectoral girdle and the ribs. This would be in accord with reports of deeper and slower breathing by Austin and Pullin (1984) and Robinson and Garlick (1986).

Experiment 7: Changes in blood pressure and heart rate under stress conditions

The previous studies were directed at measuring changes in posture, movement patterns and co-ordination. The underlying thesis being that if we adapt more successfully to stressful situations, we will see improvements in posture and movement patterns. An alternative and reliable measure of stress levels is systolic blood pressure. Consequently the following study was conducted to test the efficacy of the Alexander Technique on stress levels and performance.

Previous reports of blood pressure reductions due to Alexander lessons have been anecdotal (Jones 1979); furthermore they did not control for stress conditions. Bent Østergaard, Michael Nielsen and I therefore decided to study the effect of the Alexander Technique on blood pressure in a group of subjects under similar stress conditions.

In order to attenuate performance-stress, musicians are increasingly taking drugs, especially beta-blockers (James, Burgoyne and Savage 1983; James, Griffith and Pearson 1977). There are, however, alternative methods for combating stress. Such methods include exercise (Feuerstein, Labbe and Kucmierczyk 1986) and the Alexander Technique (Tinbergen 1974, Stevens 1987, 1993). The aim of the study was to compare the effectiveness of the Alexander Technique in reducing performance induced stress and other methods of reducing stress.

Methods

Thirty nine members of the Aarhus Symphony Orchestra, Aarhus, Denmark, agreed to participate in the study, and were randomly assigned to one of four groups: these being exercise, drug, Alexander and placebo groups. Musicians receiving medication or other medical treatments were excluded from the study.

Heart rate and blood pressure measurements were obtained prior to the musicians giving two concert performances separated by eight weeks, during which time the various groups underwent training.

Those in the exercise group ran seven km, three times per week for eight weeks; the Alexander group received 20 Alexander lessons from a professional Alexander teacher during the same period; the drug group took 40mg propranolol (a Beta blocker) 90 minutes before the second concert performance; the placebo group took an identical looking placebo 90 minutes before the second concert. Heart rate (HR) and blood pressure

(BP) were taken as measures of stress.

Phase five diastolic BP was measured using a sphygmomanometer and read blindly throughout the study: the mean of three measurements being obtained. All recordings were made at the same time of the day for each subject, after they had rested for at least five minutes. Heart rate was taken over one minute.

Measurements for both concerts were made just before the first rehearsal, before the final rehearsal and before the concert. The measurements from the first rehearsal were in order to familiarise the musicians with the measurement procedures. In addition each participant completed a questionnaire in order to subjectively assess the effects of the intervention programme.

Results

Comparing the two pre concert measurements the following were found. In the exercise group (7 men and 3 women, mean age 36 years) HR dropped by an average of 10 beats per minute ($P < 0.05$), otherwise there were no significant changes. In the Alexander group (5 men and 5 women, mean age 39 years) there was no significant change in HR but systolic BP dropped significantly (8mm Hg, $P < 0.02$). In the propranolol group (5 men and 2 women, mean age 35 years) there was also a non-significant change in HR and again systolic BP dropped significantly (9mm Hg, $P < 0.02$). In the placebo group (4 men and 1 woman, mean age 33 years) there were no significant changes in HR or BP.

Discussion

The accuracy of measurement of blood pressure is notoriously low: The small changes in blood pressure measured (This is not surprising as we were dealing with normal healthy people) indicate that more accurate measurement techniques would increase the reliability of such data. Also the groups were small and there was no true control group for either the exercise or the Alexander groups. A larger scale study with hypertensive subjects seems indicated to answer both of the defects. The importance of such trials is underlined by the report that a 6 mm Hg decrease in diastolic blood pressure, if maintained, reduces stroke by 42% and one form of heart attack, myocardial infarction (MI) by 14% (Collins et al, 1990) and that the drugs usually used to produce these results are thought to possibly cause an increase in MI of 10-15% (Hennekens and Buring, 1993).

Conclusions

Although these findings need to be confirmed by others, it seems appropriate that serious consideration be given to regimes other than medication in order to combat performance-related stress. For example it is noted that there was no rise in systolic BP in the drug group before the second concert suggesting an inability to respond at all to the demands of the situation, as is underlined in the subjective reports.

Subjective reports

94% of the participants commented that taking part in the study had produced benefits for the orchestra as a whole. All of these described the benefit as social, while 48% also described it as musical. Eight musicians in the Alexander group, eight in the exercise group and three in the drug group reported that their intervention had led to lower unwanted stress (or more correctly, distress). In addition eight in the Alexander group and eight in the exercise group would like to continue their training, and would recommend it to others, whereas only two in the drug group might take a beta-blocker on another occasion and would recommend this form of intervention to others.

Typical descriptions of the interventions were:

"A feeling of a surplus of energy to solve daily life jobs and situations" (Alexander group)

"Improvement in breathing" (Alexander group)

"Surprised over the well-being I have gained due to running" (exercise group)

"Increased general well-being" (exercise group)

"Totally indifferent towards my job, a deteriorated concentration - a feeling of being isolated from everything - and hammering in my fingers and toes" (drug group)

"If you become totally de-stressed and cold after taking a beta-blocker, the result is that what you play becomes cold and uninteresting" (drug group)

The findings of Alexander research in the light of current scientific concepts

The results of the various experiments presented here suggest that Alexander training has a beneficial effect on posture, movement patterns and performance as well as some physiological functions. What mechanisms underlie these observed effects? This is a difficult question to answer. However for changes in posture and movement patterns it is highly probable that proprioception, the stretch reflex, elasticity, the mechanical properties of muscles, postural reflexes and voluntary neurological activity are important components. We will consider each in turn.

Proprioception

The control of posture and movement requires information on the position of one body part relative to another (as well as many other factors). This orientation is obtained through proprioceptive organs located in the muscles, the joints and the skin. The known receptors in muscle are the Golgi tendon organs, muscle spindles, Paciniform corpuscles and free nerve endings.

Golgi tendon organs

Golgi tendon organs, generally found at the musculo-tendinous junction, are composed of collagen strands derived from the tendon enclosed by a capsule of connective tissue. The strands connect to several (10 to 20) individual muscle fibres. It is believed that the Golgi tendon organs respond to the stretching of the collagen strands within the capsule.

Muscle Spindles

Some of the connections to muscle spindles and tendon organs are shown in Figure 10. The central section of a spindle (Figure 11) is not contractile but passively elastic and surrounded by a helical coil of sensory nerve endings.

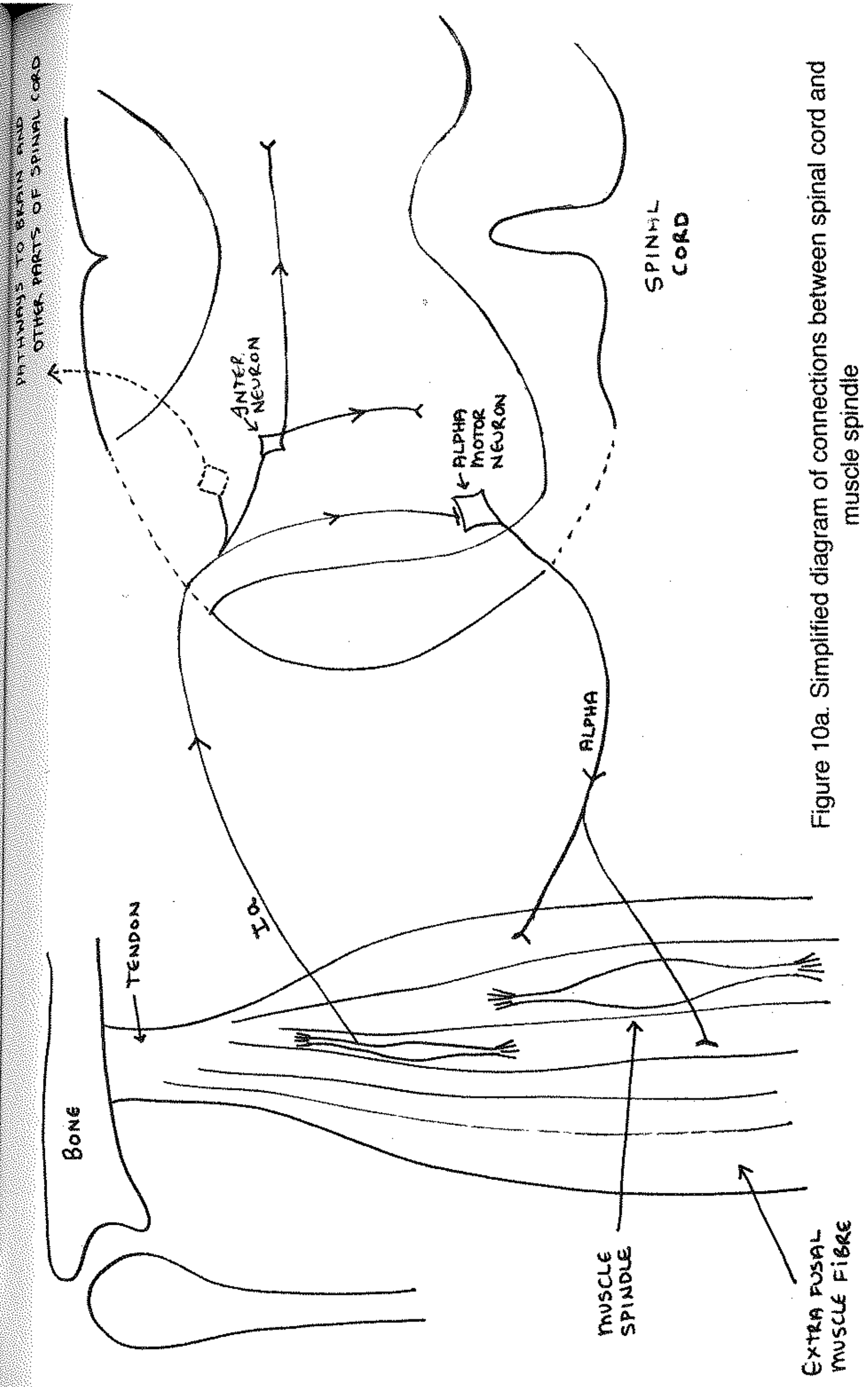

Figure 10a. Simplified diagram of connections between spinal cord and muscle spindle

From the tendons at each end of the main muscle, some collagen fibres merge with the three-dimensional network of connective tissue that runs between and around the large, powerful, extrafusal muscle fibres. Further fine collagen fibres lead from this connective tissue network to the ends of the delicate intrafusal muscle fibres.

Paciniform corpuscles

Paciniform corpuscles are often found in the vicinity of the Golgi tendon organs. They resemble the Paciniform corpuscles found in the skin with a similar function are considered to be rapidly adapting end organs sensitive to high frequency vibrations.

Free nerve endings

Additional sensory innervation is accomplished by free nerve endings which are generally ubiquitous in muscle. Free nerve endings are found in muscles and around joints. Free nerve endings are chemosensitive, that is they are activated by chemicals as well as by mechanical stress. For example lactic acid is produced by contraction and stimulates these afferents in muscle (Rotto and Kaufman, 1988).

In turn, it has been shown that the afferents potently activate both static and dynamic gamma motoneurones in both the same muscle and those surrounding it (Johannson, Djupsjoebacka and Sjoelander,1993).

Joint receptors

Joint ligaments and capsules have Ruffini, Golgi tendon organ-like, as well as free nerve endings in them. The first two can be exquisitely sensitive, able to respond to stretch forces as small as 0.05 N, approximately 5 grams weight (in the cat), while the latter seems only to be activated by abnormal mechanical stresses or inflammatory type chemicals.

Stretch on the first two receptor types is thought to have powerful influence on the gamma motoneurones, markedly changing the discharge of the spindle afferents. Thus, it is now thought that they

contribute to the modulation of muscle stiffness and therefore to the control of the stability of the knee joint (Johansson, Sjoelander and Sojla, 1991). They may also contribute to the sense of movement and position of the knee (Simon et al, 1984). It will be interesting to see if these findings are confirmed in other joint ligaments, particularly those in the spine.

Stretch Reflex

The stretch reflex is likely to play a major role in muscle action under natural conditions. Simply stated, if a muscle is stretched sensors imbedded in it called spindles convey information about the degree and rate of stretch of the muscle. Spindles are so called because they are shaped like old fashioned spindles used to draw out wool into thread. Figure 11a shows one. The Latin name for a spindle is *fusus* and so muscle fibres within a spindle are called intra fusal muscle fibres, whilst those outside it are called extra fusal muscle fibres.

When an external force stretches a muscle, the large extra fusal muscle fibres are stretched by the pull on the tendon (see Figure 10a). This in turn stretches the spindle and its intrafusal muscle fibres activating sensory nerve endings near the centre of the spindle (see Figure 11a). Returning to Figure 10a we can follow the pathway (called Ia) from these nerve endings .This transmits a signal to the alpha motor neurones in the spinal cord. These in turn bring about the contraction of the extrafusal fibres within the same muscle, tending to return the muscle to its original length. This is called the simple stretch reflex.

The simple stretch reflex is an example of a simple or monosynaptic reflex, consisting of two neurones connected by one synapse. Synapse is derived from the Greek *synapses,* meaning junction and refers to the area where one nerve communicates to another. Reflexes involving more than one synapse, i.e. three or more neurones, are referred to as polysynaptic. This is also illustrated in Figure 10a. The spindle's sensory neurone branches within the spinal cord where it forms several synapses:

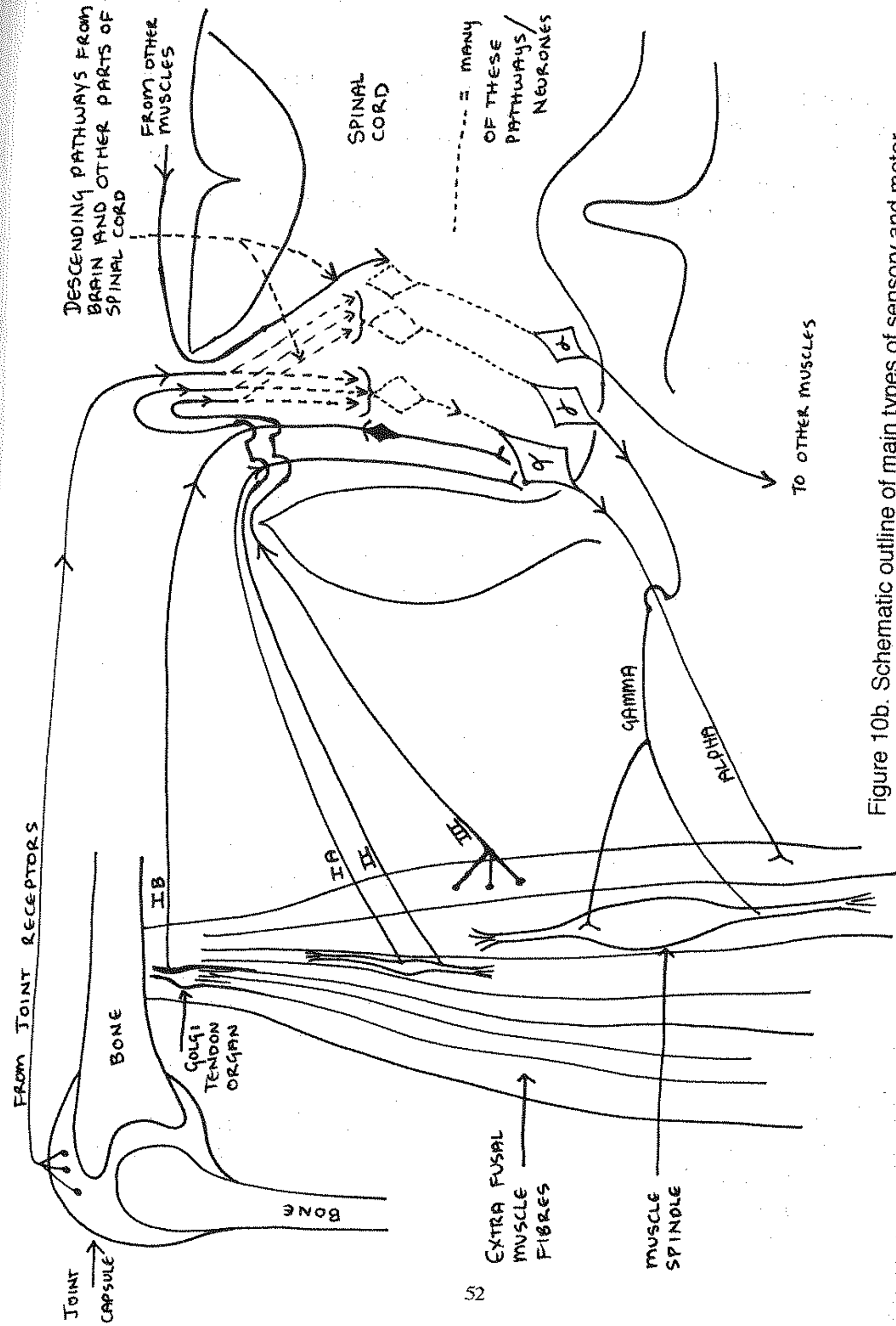

Figure 10b. Schematic outline of main types of sensory and motor connections between *muscle, joints and the spinal cord*

(a) with the alpha motor neurones, (b) with, which relay information to the brain and to other motor neurones of the spinal cord. Through these we can sense our muscles and they can affect other muscles. This is used in walking to allow one leg to support the body whilst the other is flexing. Following the pathways shown in Figure 10b, let us look more closely at the connections between a muscle and the central nervous system.

Sensory connections

There are two types of receptors in the spindle, called primary and secondary receptors (Figures 11a and 11b).

Type Ia (pronounced "one a") sensory nerves, often called afferents, run from the primary receptors of a muscle spindle to the spinal cord (hence their name: muscle spindle afferents). The primary receptors are particularly sensitive to small rapid stretches. The fast Ia sensory nerves will conduct this information rapidly to the central nervous system (CNS). They go directly to the alpha motor neurones, exciting them to fire. This is the simple stretch reflex referred to earlier and shown in Figure 10a.

Type Ib Golgi Tendon Afferents go from the Golgi tendon organs to the spinal cord synapsing to an inhibitory inter neurone which tends to prevent the alpha motor neurones from firing. It is believed that these modulate the effects of the simple stretch reflex, fine tuning it to the requirements of the situation of the muscle because of the great sensitivity of the tendon organs.

Type II spindle afferents go from the secondary receptors in the spindle to the spinal cord. Secondary receptors respond more to the state of stretch rather than how quickly it is changing. The type II afferents are slower conductors than the type I. These lead to a network of inter neurones which in turn lead to both alpha and gamma motor neurones serving the same muscle and other muscles.

Type III and IV muscle afferents go from free nerve endings in the muscle to a network of inter neurones which in turn lead to both alpha and gamma motor neurones serving the same muscle and other muscles.

Sensory nerves from joint receptors lead to a network of inter neurones which in turn lead to both alpha and gamma motor neurones serving the same muscle and other muscles.

Motor connections

Alpha motor neurones connect the spinal cord to the extra fusal muscle fibres. When the neurone fires it causes the muscle fibres to contract.

Gamma motor neurones connect the spinal cord to the intra fusal muscle fibres. When the neurone fires it causes the muscle fibres to contract. Gamma motor neurones also have connections to other muscles.

A spindle's sensitivity to stretch is modified by gamma fusimotor neurones. Some of these gamma fusimotor neurones excite the intrafusal muscle fibres (Figures 10b and 11a) while others stimulate the sensory endings directly (not shown in the diagrams) (Boyd 1986).

Descending and ascending pathways

Descending pathways from the brain and other parts of the spinal cord act on the alpha and gamma motor neurones via a network of interneurones. In figure 10 they are shown at the rear (posterior) of the cord, this is anatomically incorrect but necessary for conceptual clarity.

Although the ascending pathways are sensory ones, ultimately leading to the brain, these are ascending motor pathways can lead to the contraction of muscles. For example when we stub our toe ascending pathways conduct messages to the appropriate segments of the spinal cord, causing motor neurones to fire and the muscles of leg and other parts to contract to pull the foot away from the source of pain.

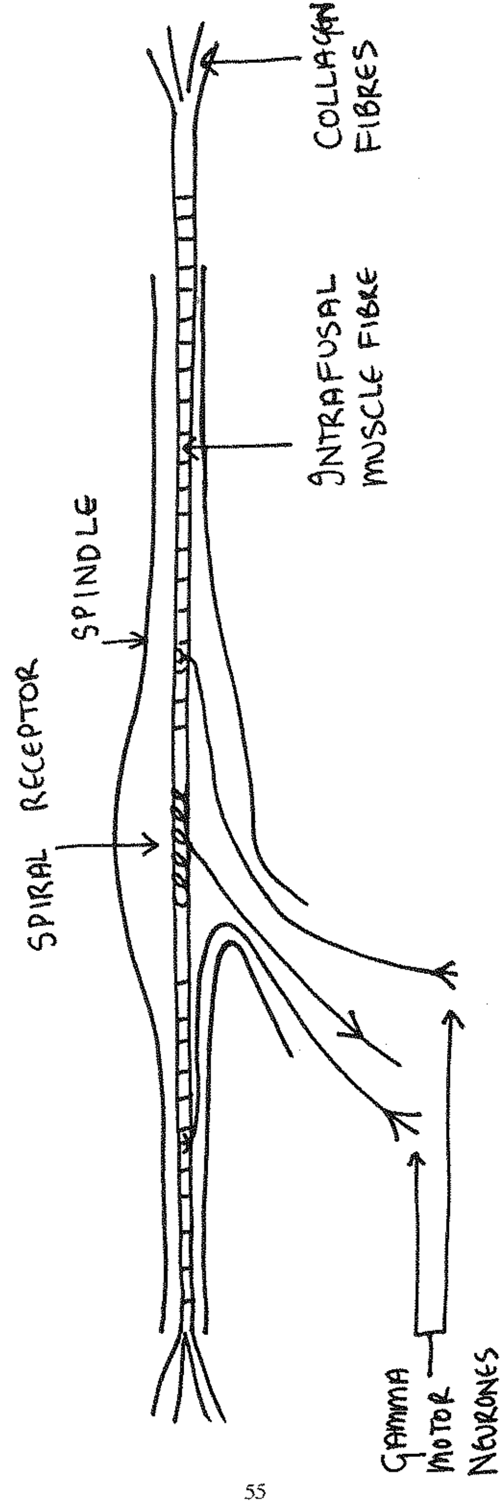

Figure 11a. General features of a muscle spindle

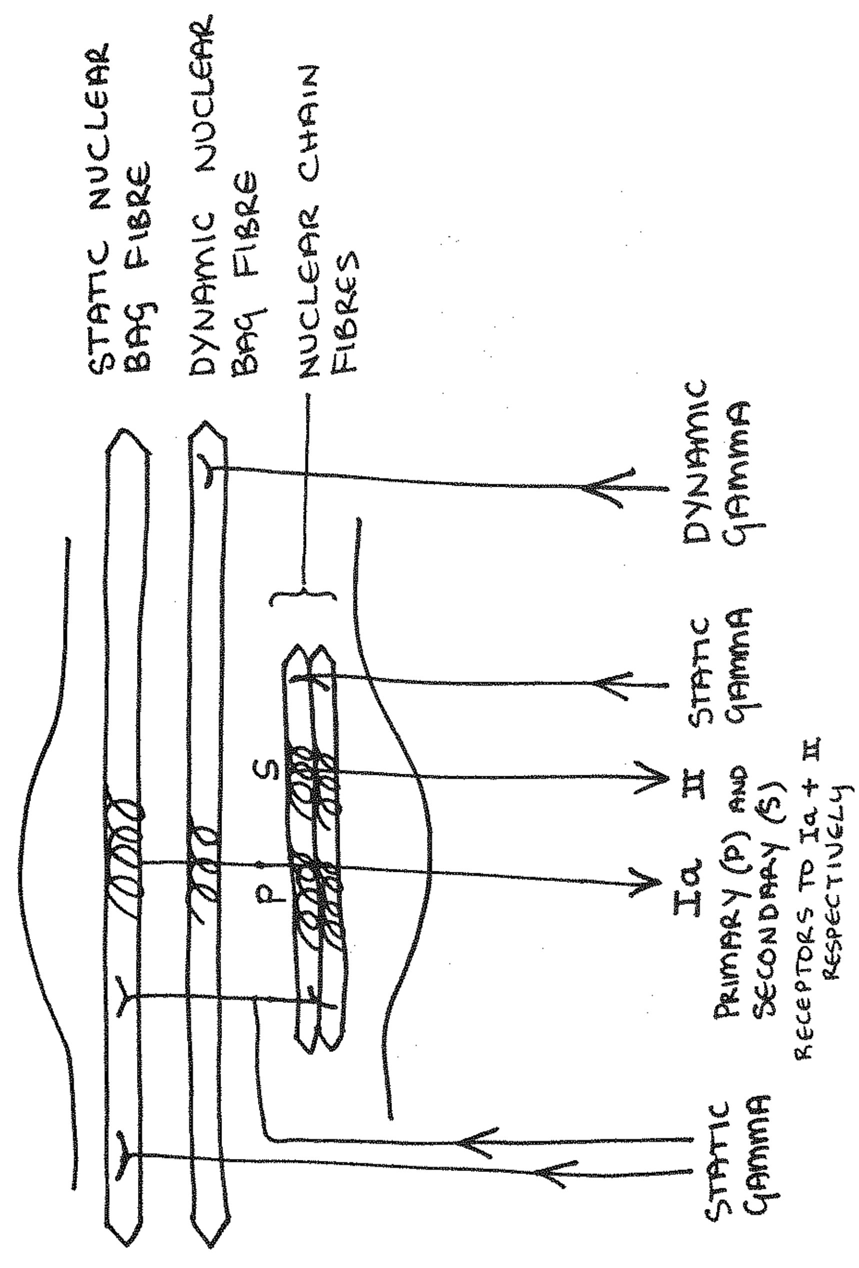

Figure 11b Diagramatic representation of a muscle spindle and its intrafusal muscle fibres showing their motor and sensory innervation

There are perhaps 1 million motor neurones in the nervous system and an estimated ten times that number of sensory cells, the remaining 99% of nerve cells being interneurones, processing the sensory inputs and formulating motor responses. Most of these interneurones are inhibitory, that is tending to prevent inappropriate activity, in our diagram only one is shown.

The brain and the stretch reflex

The arousal level of the brain has a powerful influence on muscle spindles (Burke 1980; Brooks 1986). The stretch reflexes are inactive during deep sleep and relaxation. However, on awakening the reflexes are suddenly switched on (Brooks 1986), signals from the brain acting via the gamma fusimotor neurones.

Fusimotor activation by descending fibres from the brain has been found, in simple language hard thinking makes you tense. In physiological language Ribot et al (1986) have shown that a cognitively demanding task increases fusimotor activity.

Brooks (1986) reports that people he characterises as "nervous" cannot switch off their stretch reflexes. He suggests that spindle sensitivity is maintained at an inappropriately high level through over activity of some gamma pathways.

"Resting Tonus"

Awake cats have stretch reflexes operating in relaxed muscles (Boyd 1980) and alert monkeys maintain postural tone in a resting limb by the activity of small calibre voluntary pathway corticospinal neurones (Brooks 1986). In awake humans neither kind of activity has been observed in a resting limb (Burke 1980; Brooks 1986). Why is this? Is this due to the experimental conditions, as are indicated in Soames and Atha's experiments (1981), in which the preparation of subjects took up to two hours.

An alternative explanation is a possibly greater differentiation in humans between postural and movement muscles (or probably more correctly motor units). Although little activity is detected using surface electrodes in normal quiet standing (Soames and Atha, 1981), needle electrodes, which are able to pick up signals from deeper muscle layers can show continuous activity (Basmajian and de Luca, 1985).

Sympathetic innervation

Recently it has been recognised, in the cat at least, that the sympathetic nervous system also innervates spindle intrafusal fibres (Ballard 1977; Grassi, Filippii and Passatore 1987). These nerves release the neurotransmitter Noradrenaline, but their precise role in spindles has yet to be identified (Boyd and Gladden 1985). According to Passatore, Grassi and Filippi (1985) it can cause activation of intrafusal muscle fibres. Further Hunt, Jami and Laporte (1982) found that it potentated fusimotor effects in the cat.

Noradrenaline and adrenaline are released from the adrenal glands into the bloodstream during emergencies and stressful situations when the sympathetic nervous system becomes more active, alerting the body and promoting powerful activity in the muscles. Perhaps the direct sympathetic innervation of spindle fibres at these times increases their sensitivity and speeds up the muscle's response and reflexes. If these sympathetic fibres are present in human spindles their action could contribute to the "jumpiness" seen in "nervous" people and to the problems facing musicians during performance.

The mutability of the stretch reflex

Depending on the individual's level of arousal, emotional state, intention, and other reflexes, the stretch reflex will vary in its responsiveness.

Stretch evoked responses can be altered by training. Professional ballet dancers lack patellar and Achilles tendon reflexes (Goode and van Hoven, 1982). Further biofeedback training has been shown to enhance or decrease the short latency response to muscle stretch (Evatt et al, 1989; Wolpaw, 1985). Finally it appears that apart from training there are considerable individual variations in different individual's responses to similarly administered stretches (Djupsjoebacka, 1994)

Spread of increased stiffness from one muscle to others

The afferent (sensory) nerves from free nerve endings are activated during static or repetitive contractions. These afferents increase the activity of the sensory nerves to the muscle spindle (called MSA's) via fusimotor reflexes in both the original muscle and those surrounding it. This in turn tends to increase muscle stiffness, setting up positive feedback loops of the form: production of metabolites (from contraction) - increased activity in MSA's - increased stiffness - increased production of metabolites. This hypothesis, to explain the chronic muscle pain reported by sufferers involved in static or repetitive muscular activity, was developed by Johansson and Sojka (1991).

Corroborating findings include that of Veiersted and Westgaard (1993), who found that people who had higher EMG's with fewer gaps in the record,(i.e. short periods of relaxation) in light repetitive tasks were more likely to develop pain. Kilbom and Persson (1987) also found a relationship between what they termed stereotyped and tensed movement patterns and muscle pain.

The spread of muscle release found in Alexander lessons may be due to an analogous, but opposite feedback cycle. i.e. reduced production of metabolites - decreased activity in MSA's - decreased stiffness - decreased production of metabolites

Elasticity

The elastic properties of various tissues and body segments has importance both for body mechanics and for the flow of nervous information. The co-operation of active muscles and the resilient elasticity of bone, tendon, ligament , muscle itself and other tissues, together with the great sensitivity of the various types of nerve endings serving them, are obvious components in a search for the mechanisms underlying the Alexander Technique.

It has been thought for some time that 40% of the energy for running comes from the release of stretched muscles and tendons (Cavagna et al. 1971). Although this has recently been questioned (Williams 1985), Alexander et al. (1985) have shown that in galloping deer and dogs the lumbar aponeurosis is an important energy store. More recently Alexander (1987) has suggested that the foot also has a powerful energy saving role in movement, due primarily to its elasticity.

An interesting observation by Maloiy, Heglund, Prager, Cavagna and Taylor (1986) is that East African women can carry loads on their heads of up to 20% of their body weight without having to use extra energy, whereas westerners cannot. Alexander (1986) has suggested that this may be due to their making more efficient use of some elastic mechanism, probably involving the vertebral column. In a later paper Heglund et al (1995) consider that the main mechanism is the improved efficiency in the use of the body as an inverted pendulum. However they do not tell us how this efficiency is improved, as is pointed out by Taylor (1995). A three dimensional movement analysis together with EMG and force plate analysis as reported earlier in this book should help in supplying the missing parts of this story.

Elastic Properties of the Spine

At its most basic level it has been suggested that the spine forms a slender elastic column (Lucas and Bresler 1961) with end supports formed by the pelvis at the sacro-iliac joint, and by the head and cervical parts of the spine through the righting reflex. It can be regarded as a compression

spring whose stiffness can be regulated by its associated muscles and abdominal and thoracic pressures (Morris, Lucas and Bresler 1961).

Recent studies however suggest that the spine has a far more active role than the above would suggest. Gracovetsky (1988) has proposed the concept of the spinal engine. He has found that the normal spinal curvatures cause the lateral bending associated with locomotion to be translated into contra-rotations at the pelvic and pectoral levels, giving rise to the typical human cross pattern gait. The arms are given an important role in this theory as they can wind up the engine in walking and running, thereby increasing the power of the pelvic rotation and assisting the legs in propulsion. This theory also suggests that the ligaments of the lumbar spine act as an elastic energy store in running, in much the same way as Alexander (1985) has proposed for quadrupeds. Thus it seems increasingly probable that the spine is not merely a compression spring.

Asmussen (1960) and Woodhull, Maltrud and Mello (1985) have shown that the centre of gravity (CG) of the head lies in front of the whole body CG and the sacroiliac joint. Engineers know that long slender columns are unstable under these kinds of conditions. Lindbeck (1985) showed that the spine is unstable in the frontal plane (making it susceptible to scoliosis). Even though the spine is reinforced in the sagittal plane, the normal curves can be still be distorted. Unbalanced forces will tend to cause buckling. Asmussen and Klausen (1962) observed that the cervical and thoracic curves increase and the lumbar curve decreases with age in a sample of 329 male Danes aged 7 to 25 years. Voutsinas and MacEwen (1986) studied a group of 251 male and 419 female Americans aged 5-20 years. They have also reported an increase in both thoracic and lumbar curves with no significant differences between males and females, except that girls had a greater lordosis than boys prior to age 15.

Alexander hypothesised that many of the respiratory, circulatory, gynaecological and digestive problems helped by his technique (Barlow 1973) were related to increases in spinal curvatures. According to Goldthwait, Brown, Swaims, Kuhns and Kerr (1941) the viscera are at least partially slung from the cervical fascia as well as the thoracic fascia by way of the pericardium to the diaphragm, and by the diaphragmatic attachments of the abdominal viscera. Only when the thoracic and cervical portions of the spine are fully extended are the viscera raised to the best functional level. Barlow's (1954,1956) photographic posture studies showed an extension of the cervical and thoracic curves, as well as of the lumbar spine, after Alexander lessons.

Personal experience of teaching the Alexander Technique suggests that students who have done a lot of heavy lifting often have pronounced lumbar curves associated with shortened lumbar muscles. Alexander (1932) in referring to exaggerated spinal curves associated with a misuse of the body, described the effect as "shortening in stature". I propose that this kind of misuse may effect the elasticity of the spine. How might this occur?

The idea of a slender elastic column is easily visualised by using a riding whip. If the whip is stood on a table and downward pressure is applied to the top it is easily bent into a C-shaped curve. Applying further pressure reveals that the whip becomes harder to bend i.e. it has become stiffer. If the whip is held so that it is bent into two curves and downward pressure is applied a marked increase in its stiffness, or resistance to further bending, is felt.

This phenomenon was systematically studied by Euler (Timoshenko 1961) who developed equations to describe such buckling. The most important in the present context states that the resistance of an elastic column to buckling is proportional to the square of the number of curves plus one. In other words a C-shaped curve has twice the resistance of a straight whip, an S-shaped curve five times and a triple curve 10 times the resistance of a straight whip. This suggests that curves are beneficial as long as they remain in balance, because reducing the number of curves weakens the structure. Thus the slumping forward observed by Asmussen and Klausen (1962) is likely to reflect a weakening of the spine.

There are, however, more ways to weaken a curve than to straighten it. Consider an archer's long bow. The tension in the string is equal to the resistance of the wood to bending. Thus if a curve in the spine is maintained by muscle shortening, the resistance of that curve to bending is

being used to resist the pull of the muscle and not to support the body. Again the spine (as a support structure) is weakened, as seen in individuals with pronounced lumbar curves.

Conversely, the lengthening of the spine resulting from the removal of unbalanced forces following Alexander lessons (Barlow 1973) may be expected to cause a lengthening of muscles, tendons and ligaments. This produces greater elastic forces. As noted earlier, Jones and Gilley (1960) demonstrated that Alexander lessons caused lengthening of the sternomastoid muscles. This could result in stretching of muscle spindles, thus activating type I muscle fibres. These factors may combine with the elastic effects giving a greater sense of ease due to the non fatiguable characteristics of these fibres.

Such an increase in the sense of ease has been reported by Tinbergen (1974) who reported that he felt his body "snap into shape"; behaviour characteristic of an elastically powered change. In addition to such subjective reports Jones (1965) has reported that the greater muscle length is correlated with decreased neck muscle activity. This is to be expected if greater reliance is placed on elastic force and less on muscular contraction.

Elastic tissue mechanics and sensory systems

Until recently connective tissues were divided into elastic and collagenous fibres, implying that the latter were inelastic. However, it is now known that collagen fibres are elastic within certain limits (Butler, Grood, Noyes and Zernicke 1978)

Ligaments and tendons, which consist largely of collagen, can tolerate forces up to 6000-8000 Newtons per square centimetre. Furthermore collagen fibres can stretch by 5-8%, tendons by 8-10% and ligaments by between 10 and 40% before breaking. (The measurement of the force across an area of material is termed stress, with the ratio of the stretch and the original length of the material termed the strain). These are valuable sources of elastic energy for movement, storing up to ten times more strain energy than muscles (Alexander and Bennet-Clark 1977; ıonsen, Edgerton and Bojsen-Møller 1988).

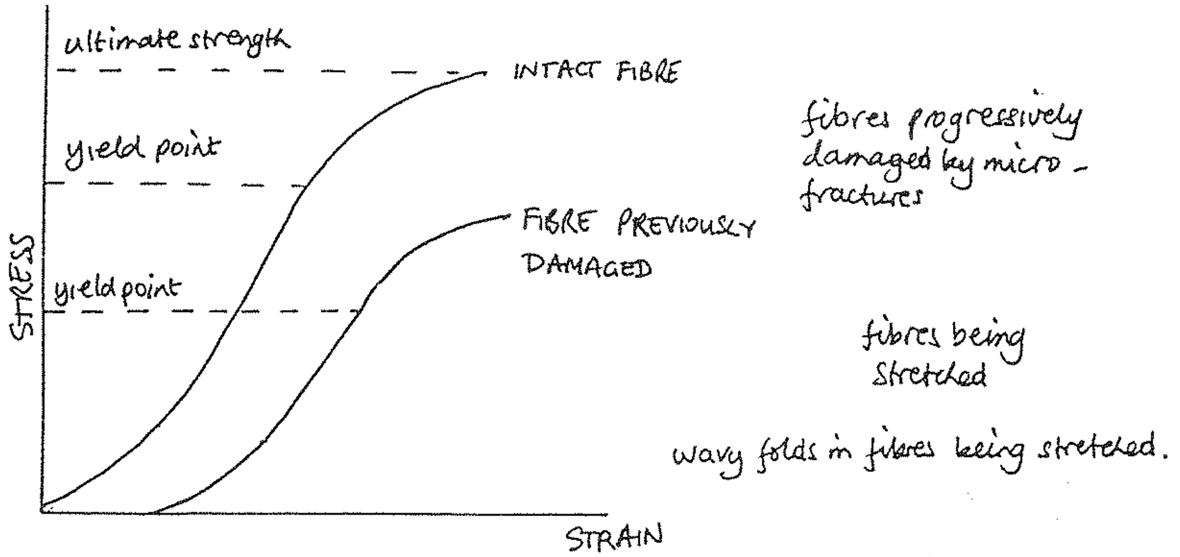

Figure 12. Stress-strain relationships in ligaments (from Bojsen-Møller 1988).

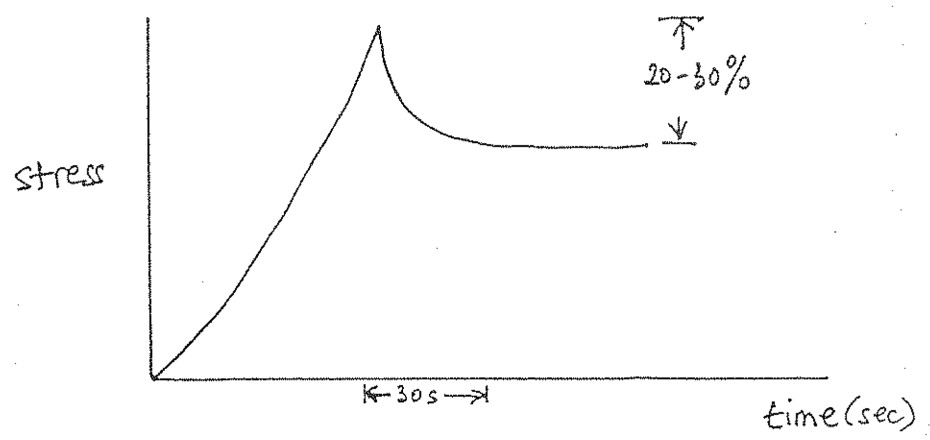

Figure 13. Stress relaxation in ligaments (from Bojsen-Møller 1988).

There are some important characteristics of the way in which tendons and ligaments react to stress and strain. Graphs of stress-strain relationships in tendons and ligaments show three different parts to the curve (Figure 12). Initially the tissue is easily stretched because the collagen fibres, which are arranged in a wavy pattern, become straightened: this is the toe portion of the curve (Viidik 1978). The straight part of the relationship represents the real elastic stiffness of the fibres as they are stretched. Eventually however a yield point is reached where the tissue is increasingly damaged causing more and more deformation until it finally fails at what is known as its ultimate strength.

Stretching a fibre beyond the yield point but not to breaking point and removing the load results in a small permanent deformation. Stretching the fibre again now results in a greater lengthening for the same load. As our proprioceptors depend on the force generated within the tissue to warn of impending damage, a damaged ligament will not be sending correct information to the central nervous system warning of the approaching yield point. Thus a damaged ligament can be the cause of further damage to itself as well as associated structures.

An additional property of ligaments that is of some importance, is that they cannot resist sustained stretch with a constant force (Figure 13). That is the stress in the material drops by 20-30%, most of it in the first 30 seconds, when under a steady stretch. This may lead to erroneous information being transmitted to the central nervous system, just as with the damaged fibre (Butler et al. 1978). For example sitting slumped in a chair for a long period of time will cause a concentration of stress on some of the ligaments of the back, holding them in a stretched position, and they will "relax" (Figure 14). On rising they may not convey the appropriate information regarding the alignment, balance and position of the back.

The increase in the height of the spine seen in Alexander students will increase the distances between the spinous processes evenly throughout the spine, stretching the supra- and inter-spinous ligaments and increasing their stiffness (Figure 15). As the spine is a composite structure, these ligaments are part of a continuum of ligaments; so, when they are stretched more and more fibres become engaged, thereby increasing

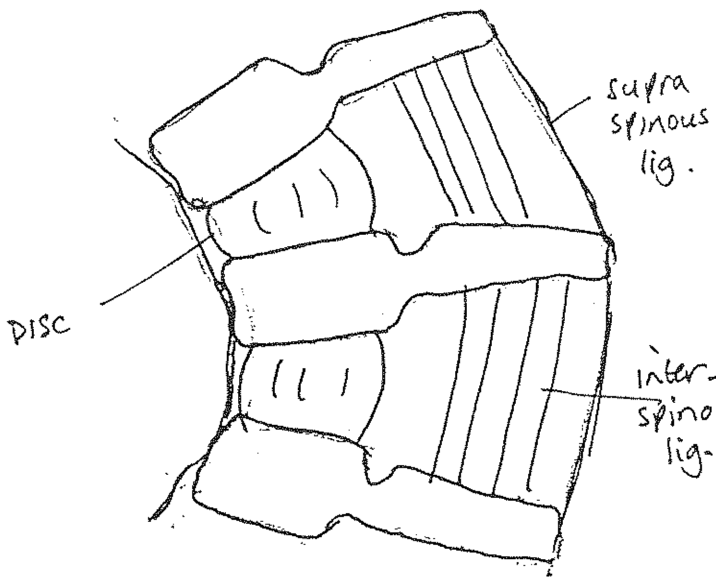

Figure 14. Possible stress relaxation in spinal ligaments (from Bojsen-Møller 1988).

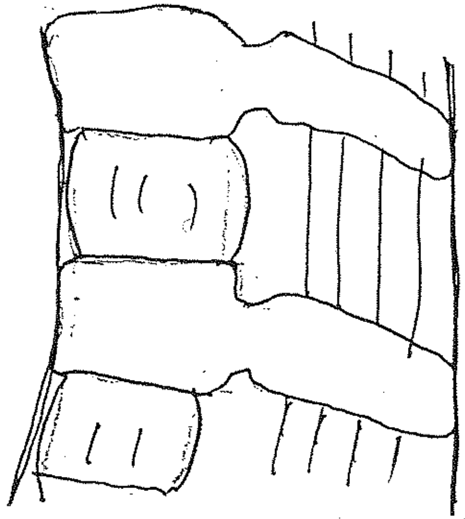

Figure 15. Possible increase in overall lengths of ligaments and heights of discs causing increased stiffness of the spine (from Bojsen-Møller 1988).

the stiffness of the whole structure. This will continue until a position is reached where very little further stretching can occur (Bojsen-Møller 1988).

This is different from the conditions of an isolated structure as it is difficult to cause damage to the tissues or for them to relax in the ways outlined earlier. Instead, the stretching out of the curves in response to the Alexander Technique improves proprioception from the ligaments, as well as from the muscle spindles and tendon organs. The role of the head and neck in this arrangement is of importance for, as the position of the head is modified and the shape of the cervical spine is changed, the afferent input to the system is also changed. Murthy et al. (1978) have shown that ventroflexion of the neck effects both alpha and gamma motor neurones in the lumbar muscles of the cat.

There have been many attempts to correct posture with the aim of reducing intradiscal pressures after Nachemson's (1976,1981) pioneering work. He showed that intradiscal pressure increased when moving from lying to standing upright. It further increased on leaning forward and again when sitting down. These findings have been interpreted as suggesting that instruction in lifting and sitting should be aimed at reducing intradiscal pressures.

However from a knowledge of the statics of slender elastic columns (Timoshenko 1961; Lucas and Bresler 1961), the force needed to buckle the column to the side (causing scoliosis) is one tenth of that which will damage the material of the column (for example the discs). This suggests that sideways buckling will occur long before disc damage.

The pressure at which sideways buckling occurs depends on three factors: i) how the material is distributed around the neutral axis, ii) the length of the column and, iii) its elastic stiffness. In humans only the latter can be changed, being achieved by changing the shape of the spine and, due to the stretching of ligaments and muscles, by increasing the height of the intervertebral discs, as shown by Jones and Gilley (1960) for the cervical spine.

Muscle

Mechanical properties

These properties need to be known to understand the variations in muscle force under different conditions. The same command, i.e. an action potential along a motor nerve, whether reflex or voluntary, can generate different forces in a motor unit. The differences in the generated forces are due to the muscle's length, its velocity of shortening or lengthening, and the state of activation of the unit before receiving the command.

Tension-length relationship

The length-tension relationship may be examined by holding a muscle, or muscle fibre at different lengths, with one tendon attached to a force transducer. All reflex arcs are severed and the force is measured for different held lengths for either maximum (tetanic) activation or when the muscle is passive.

The conditions measured have been:

(i) No change in length when the measurement is taken (called an isometric contraction).

(ii) The muscle is allowed to shorten due to the contraction.

(iii) The muscle is lengthened as it contracts.

These correspond to (i) holding a glass in a hand, (ii) lifting a leg prior to kicking a ball, (iii) the stretching of the thigh muscles when walking down a flight of stairs.

The curves produced are shown in Figure 16 (after Hill 1953). The cause of curve (a) in Figure 16 is shown in Figure 17 (after Roberts 1978) and the cause of curve (c) in Figure 16 is shown in Figure 18 (after Gordon, Huxley and Julian 1966). The curve for a complete muscle is more rounded due to the summation of the effects of the many sarcomeres.

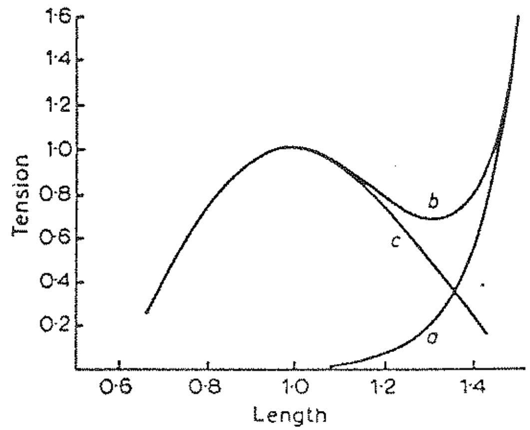

Figure 16. Typical tension-length graph for striated muscle: (a) passive; (b) tetanic forces for various lengths under isometric conditions with repetitive stimulation; (c) force due to the contractile elements, found by subtracting (a) from (b) (after Hill 1953)

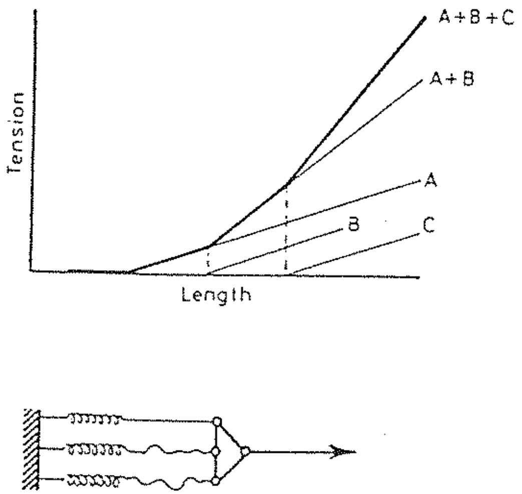

Figure 17. Graph of tension and length for a simplified system of three springs in parallel, each with a different slack length. Progressive stretching of the whole system sequentially activates the springs, with their tensions summating. This can be compared with curve (a) in the previous figure (redrawn from Roberts 1978)

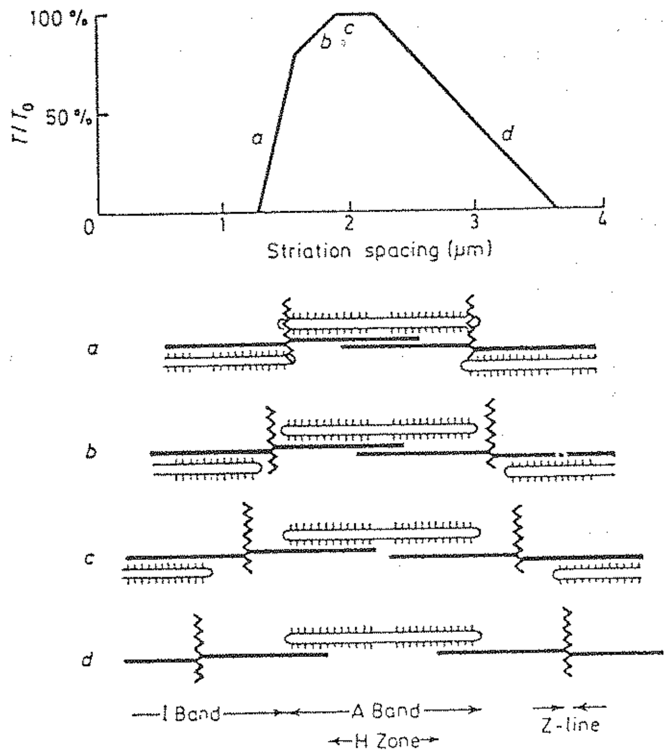

Figure 18. Graph of tension and length for a single sarcomere for different overlaps of actin and myosin filaments. (a) Myosin penetrates Z-line or is longitudinally compressed. (b) Actin engages with cross bridges pulling in both directions. (c) Full occupation of cross bridges. (d) Some cross bridges not engaging (redrawn from Gordon et. al. 1966)

Force-velocity relationship

The force-velocity relationship can be explored using a catch device so that the force resisting a tetanized muscle can be altered almost instantaneously. If the force is less than that of the muscle, the muscle shortens. The speed of shortening depending on the difference between the forces. The same procedure can be used to explore different lengthening velocities by applying varying forces that are greater than those of the muscle. Figure 19 (after Curtin and Davies 1972) illustrates the relationship obtained.

Effects of partial activation

So far we have only considered full activation (tetanus) and no activation (passive). There is a difference between the response of a maximally contracted muscle and a partially activated one as shown in Figure 20 (after Joyce, Rack and Westbury 1969). A reduction of force below the isometric value in a partially activated muscle has functional significance in the magnet reaction, and is a possible mechanism for the muscle lengthening seen in Alexander lessons. This suggests that as the level of muscle activity reduces, the relatively constant lengthening force of bones and other elastic tissues on muscles, can have the effect of making a muscle longer under the influence of Alexander directions, as long as the stretch reflex is not activated.

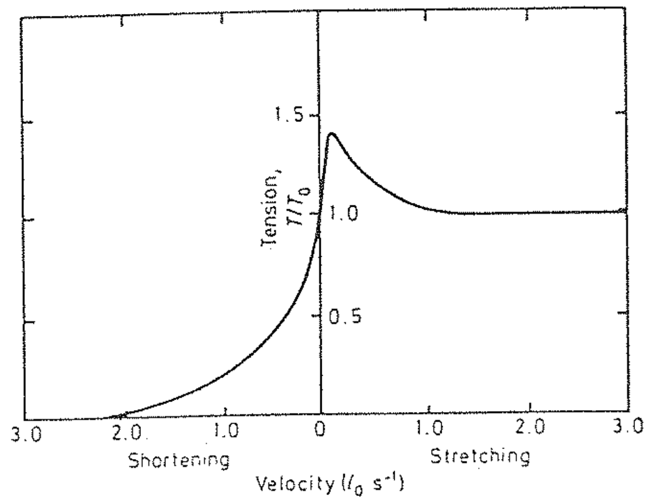

Figure 19. Tension vs velocity graph for tetanized muscle. For moderate speed forcible extensions the force developed is greater than isometric (after Curtin and Davies 1972)

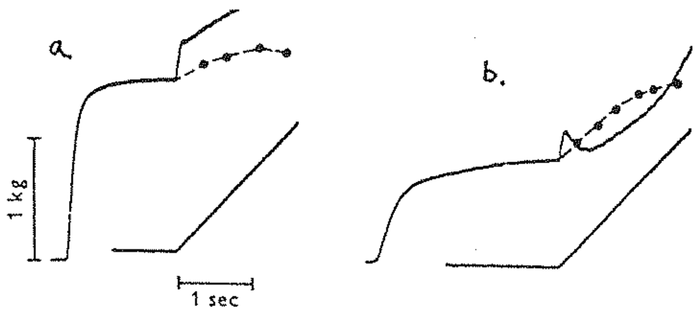

Figure 20. Effect of induced lengthening on the tension recorded in isolated cat soleus muscle under constant stimulation (a) 50hz, (b) 7hz. The dotted line shows isometric tensions at lengths indicated. Note the reduction in tension to below isometric during lengthening under condition (b) (redrawn from Joyce, Rack and Westbury 1969)

Difference in response due to different previous conditions

A stimulus applied to a previously inactive muscle produces a lower force than one added to an already existing stimulus. The latter effect can be long lasting as shown in Figure 21 (after Burke, Rudomin and Zajac 1970). This is perhaps the physiological basis for the requirement of the inhibition of any preparation to act for the prevention of unwanted muscular contractions in Alexander training. It would also explain how, for example, latent postural reflex effects could affect a voluntarily initiated movement or posture.

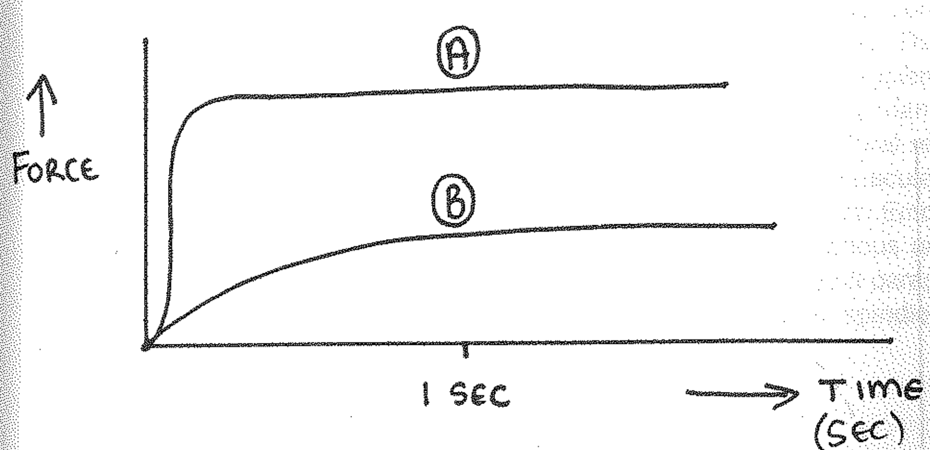

Figure 21. Enhancement of force due to a single high frequency stimulation superimposed on a low frequency train of impulses (a). Force due to low frequency train shown by (b). (redrawn from Burke, Rudomin and Zajac 1970)

Effect of stretch reflex on muscle stiffness

The effect of the stretch reflex on these properties is to compensate for the greater drop in force seen in a shortening muscle compared to the increase in force observed during stretch. This would appear to allow muscle stiffness to become more nearly constant, as shown in Figure 22

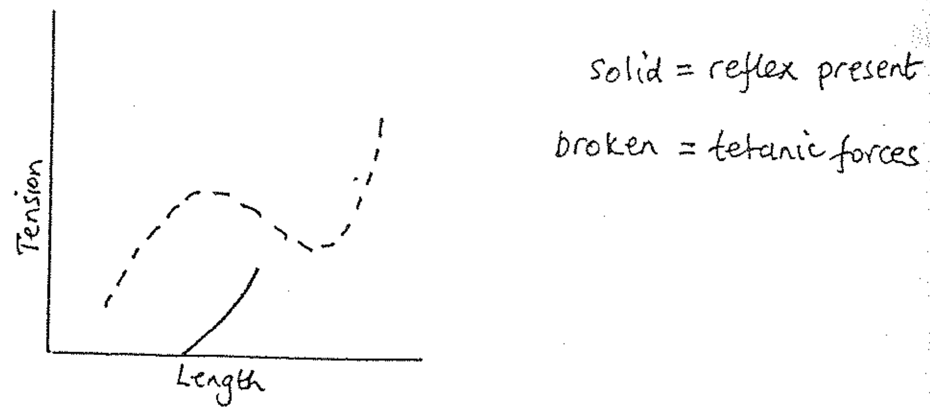

Figure 22. The relatively constant stiffness of reflexly active muscle (redrawn from Roberts 1978)

Fibre types and functions

Muscles can be misused by not using the appropriate types of muscle fibres for posture. Type I fibres are red and though weak and slow acting are highly resistant to fatigue. Using type II B fibres which are white in colour, stronger and quick acting but quickly fatiguable, so long term stimulation could lead to flaccidity in such muscles, compensatory tensing in others and poor posture. One of the differences observed between the experienced Alexander subject and non-Alexander subjects is that Alexander subjects have softer superficial muscles and a more upright posture. Normal subjects on the other hand tend to have a mixture of either stiffened or flaccid superficial muscles.

Type II muscle fibres tend to be triggered by direct connections from the motor cortex, whereas type I fibres tend not to be directly under conscious control. Type I fibres can be activated by the stretch reflex. The sensitivity of the spindle to stretch is controlled by the fusimotor system which is not under conscious control, itself being influenced by many other reflex systems, including the postural reflexes. If the postural reflexes are adversely modified, for example by prolonged muscular shortening, the type I fibres may not be called upon to contract. Emotional factors can also influence the responsiveness of the various reflexes. It is interesting to note in this respect that sympathetic and parasympathetic nerve endings have been observed in muscle spindles (Ballard 1977, Boyd & Gladden 1985).

Muscle activity in standing

Little evidence of stretch reflex activity in quiet standing in normal subjects was reported by Soames and Atha (1981), being either absent, infrequent or transient in the 18 muscles they studied. In any muscle recording experiment a relatively long preparation period is required. This may well cause fatigue and boredom. As alertness is a prime necessity for the fusimotor system to operate (Burke, Mckeon, Skuse and Westerman 1980), the results of Soames and Atha are not surprising.

Studies by Basmajian (1985) and Garlick (1988) suggest that stretch reflex activity is to be found in the deeper muscle layers during quiet standing, with no activity being evident in the surface layers. This supports the view of earlier anatomists, who suggested that the superficial muscle layers are primarily for expression and movement and the deeper layers mainly postural. Although this may not always be true, postural stability and voluntary movements are controlled separately. For example patients with basal ganglia defects can have a typical bent forward head posture but make a voluntary movement to bring it into the normal upright position (Martin 1967).

The postural muscles also tend to have a greater proportion of type I fibres while the superficial muscles have more type II fibres. For example, soleus has 70-80% type I fibres (Edgerton et al 1975) whereas at the other extreme biceps is a rare example of a muscle with a majority of type II fibres (Schantz and Henriksson 1983) reflecting its predominantly movement role. In the lumbar spine multifidus and longissimus have 57-62% type I fibres with an approximately even number of type IIA and type IIB fibres (Thortensson and Carlson 1987). These have a mixed role being involved both in support and movement, including locomotion (Thortensson et al 1982).

Recruitment order

Experimentally induced contractions of neck muscles can change the recruitment order of individual fibres (Garlick 1986). Normally the weakest but longest lasting fibres are triggered first with faster and stronger ones coming in later. This gives a smooth, easy feeling to the movement. When muscles are voluntarily or reflexly inappropriately tensed, this order may be changed so that the movement pattern becomes abnormal. Conversely it is tempting to speculate that the de contractions reported by Jones (1965) will tend to return the recruitment order to normal, especially as the stretching of neck muscles in cats has been shown to cause recruitment in size order in lumbar motor neurones (Murthy et al. 1978).

The Brain

So far only physical factors have been considered but the Alexander Technique involves mental processes. Questions arise such as: "How can we stop activating muscles inappropriately?" or "If the Technique is about making changes by thinking consciously, how can we be using subconscious processes such as reflexes?"

These questions can be approached by looking at the brain mechanisms underlying planned and spontaneous movements.

Readiness potential

Preplanned Movements

In 1964 Kornhuber and Deecke discovered a negative voltage, called the readiness potential (RP) is set up in the cortex about one second before brief voluntary movements. The existence of the preparatory intention was underlined by Lassen et al (1978) who found that, when a subject only performed a hand movement in their imagination there was an increase in blood flow to the same brain areas as found by Kornhuber and Deecke (precentral, parietal and the supplemental motor cortex). These findings were extended by Roland et. al. (1980) to mentally carried out complex learnt tasks.

For smooth continuous movements the RP starts significantly earlier. Becker et al (1976) found such movements were preceded by an RP which began up to two seconds before (average 1,3s).

Spontaneous Movements and Inhibition

Libet (1985) found that a readiness potential (RP) is also set up in the cortex some 500ms before a spontaneous movement begins. It appears that the RP begins about 300ms before the subject is conscious of having chosen to move. However in the last 200ms before muscle activity begins the movement can be aborted.

Some of the problems of dealing with habit can be explained if a voluntary action is preceded by subconscious preplanning. Bower (1986) reports Libet as saying that "no matter how much silent choice-making you engage in, the same unconscious processes come into play just before you act". This appears similar to the unconscious processes that Alexander was dealing with as he developed his technique for detecting and inhibiting habits. From Libet's work it appears there is a 200ms period in which to inhibit the results of such unconscious processes, probably including postural preparations (see below), after the detection of a spontaneous desire to move.

Presumably the pattern of motor commands is being changed by modifying reflex or other neural pathways (for a further discussion on this point see later). By maintaining conscious attention to both the inhibition and to the desired postural preparations, it is possible to continue the inhibition of the unwanted subconscious preparation and to construct the new consciously chosen ones. The new postural preparations are arrived at by a process of observation and experiment using the criteria of freedom from unnecessary limb stiffness, neck and trunk shortening (i.e. no increases in spinal curvatures), an appropriate and freely maintained head attitude and more efficient movement patterns which do not disturb the subject's posture. Speaking of this process, Alexander said (Barlow 1973)

"You come to learn to inhibit and direct your activity. You learn first to inhibit the habitual reaction to certain classes of stimuli and second to direct yourself consciously in such a way as to affect certain muscular pulls."

Postural adjustments and postural preparations

Before a voluntary movement, for example lifting a leg, there is a process of postural adjustment, presumably to prepare the body for the new condition, which is initiated by the cortex (Gahery and Massion 1981). However, if the movement is made passively i.e. someone else lifts the leg, then the anticipatory postural adjustments do not occur (Bouisset and Zattara 1981).

This may account for the observations of Jones (1965) and Jones and Hanson (1970) that in Alexander lessons movements are immediately improved when the subject is guided, as measured photographically and by a force plate. As the student learns the process described above they also learn to bring about this improved pattern at will by improving their postural preparations (Jones et al. 1959 and my own experiments). Pre movement postural adjustments may also go some way to explain the underlying neurology of the startle pattern.

Until now Bouisset and Zattara's (1981) phrase "postural adjustment" has been used. However, Gahery (1987) suggests that this should be used as a generic term with the use of "postural preparations" for changes in posture which clearly precede a movement, with the use of "postural accompaniments" for postural changes about the time of onset of the movement and "postural reactions" for those that take place after movement begins. The changes in posture brought about in the Alexander Technique clearly precede movement and should therefore be termed postural preparations (although it is also concerned with postural accompaniments and reactions).

Further Gahery and Massion (1981) suggest that postural accompaniments and reactions are regulated from the brain stem, whereas postural preparations are cortical. As these can take place very closely in time they may be confused. This may be a possible explanation for the discrepancies observed with neck reflex effects.

Returning to the example of moving a leg, one function of muscles is to produce the movement and this is produced by a motor command. Before this however, the body prepares for the intended movement by moving the centre of gravity over the other leg or some other supporting part. This is to maintain the equilibrium of the body. In addition, parts of the body will adjust their position relative to each other i.e. posture changes. Thus we see an interplay between movement, equilibrium and posture of a feedforward kind. Further, all of these are influenced by the integrity of the nervous system, bones, muscles and other connective tissue, the habits and other behavioural aspects of the individual (Massion 1993)

Touch

Effects

Most Alexander teachers use touch to teach and to guide movements. What does touch do in physiological terms? Touch, especially if it is unexpected, abolishes the alpha rhythm (Adrian and Matthews 1934). This brain rhythm is typically seen when a subject is sitting or lying quietly with the eyes closed or unfocused. It also changes the blood flow in the cerebral cortex to that characteristic of greater alertness (Ingvar 1975; Lassen, Ingvar and Skinhaaj 1978). This may explain Jones' finding of normal alert brain activity in Alexander subjects (Jones 1971).

Attention may also sensitise us to receiving touch. In a fascinating experiment Roland (1981) reports that when a human subject pays attention to a finger that is about to be stimulated i.e.. before the stimulus is applied, there is an increase in blood flow to the parts of the somatosensory cortex that are involved in receiving signals from the fingers. It indicates how the brain can be activated by conscious attention to be able to receive signals due to touch. This may explain how we can learn to be increasingly perceptive to what we are touching, or what is touching us.

Even light touch on the sole of the foot elicits the supporting reaction of the leg - extending it (Roberts 1978). Nerve cells specialised for sensing touch are called cutaneous mechanoreceptors. It is now known that they contribute to proprioception (McClosky 1978) and give an important background facilitation for motor commands (Lewis and Porter 1974). Mechanoreceptors on the soles of the feet were found to have a marked effect on postural sway by Magnusson et al (1990),

The role of touch in proprioception helps to explain why it is possible to feel more accurately what the body is doing during an Alexander lesson. Its role in facilitating antigravity responses and motor commands may help in the optimising of recruitment order, thereby allowing more efficient, easy and graceful movement to occur.

Conscious experience of touch

Libet (1982) observed that when a subject's skin is stimulated electrically it takes about 500ms for the brain consciously to experience it. However the subject reports feeling the stimulus at the same time as it was administered. Libet hypothesised that the referral of the experience backwards in time was automatic. Furthermore, this reaction was triggered by the first cortical response to the fast specific messages sent by the stimulated sensory nerves in the skin.

In his most recent work Libet (1989) has reported that the 500ms delay occurs in the thalamus. He also reported that some individuals were able to perceive the stimulation he was giving them (direct to the thalamus in this case) well before the 500ms had elapsed. In some cases the recognition was almost instantaneous. It is as though the cortex is able to recognise a pattern well before it is fully formed. This is what presumably happens when we recognise someone at a glance.

Perception then is a form of guessing, which can be trained, as for example in the way an experienced teacher can quickly recognise a pupil's problems when a student hardly knows where to begin.

Attention is probably a vital factor in such perception. A large number of investigations have been carried out into the effects of somatosensory inputs on the brain and subjects experiences. The degree of attention the subject was able to bring to bear on a stimulus had a marked effect on the cortical responses and on the subjects ability to perceive the stimulus accurately (Desmedt and Robertson 1977). It would seem likely that the ability to attend to proprioceptive sensations would have a similar increase in subjects abilities to perceive proprioceptive stimuli accurately.

Responses To Overbalancing And Movement

Libet's reports have some similarities with those of rapid responses to overbalancing. Roberts (1975) showed that subjects could anticipate overbalancing and produce a rapid reaction which pre-empted the need for a later and slower reflex reaction. Such an anticipatory reaction though seemingly automatic is learned and cortical. Roberts suggests that these are not reflexes in the classical sense, although they are normally below the level of consciousness. This may explain why posture and movement are subject to habit and yet can be changed.

Roberts (1978) has proposed the concept of Anticipatory Pre-emptive Reactions which, though cortical and learned, quickly become habitual. He suggests that the initial attempts at balancing in young animals, in which large poorly co-ordinated movements are gradually refined, represents the learning of such reactions. These may be related to the postural preparations for movement studied by Gahery and Massion (1981).

Experiments involving induced hopping (by pulling on a rope attached the subjects waist, whilst standing on one leg) have shown that a subject either performs a reflex hop (of long latency) or, by anticipating the imposed toppling movement, initiates the hop before the reflex has time to operate (Roberts 1975). Such a faster response has obvious survival advantages.

Anticipatory reactions and Libet's (1989) thalamic stimulation work may also go some way to explain how subjects may be trained to detect and inhibit inappropriate postural preparations before they have time to become imposed on the body.

Startle Pattern

The startle pattern is a stereotyped postural response to an unexpected loud noise (for example), it can be regarded as a "total reflex", i.e. it involves the whole body, it was first studied by Landis and Hunt (1939). Jones and Kennedy (1951) found that in the startle pattern the head stayed at the same angle to the vertical as in the normal posture and only dorsiflexed relative to the neck, with both the head and neck being displaced forwards. The neck and trunk are shortened; the chest is flattened; the cervical and thoracic curves are increased, while the lumbar is decreased; the centre of balance seems to move forward; the shoulders are raised and drawn forwards; the arms extended downwards and the legs are flexed, Jones and Kennedy (1951) observed there to be a time course to the response. It is first (and most strongly) observed in the sternomastoid and trapezius muscles, spreading from these in approximately 500ms to the trunk and limbs.

These earlier observations are questioned in later force plate studies which showed as initial leg extension i.e. the person "jumped" (Jones 1979). Unfortunately Jones did not perform a check on the time course of the changes.

Postural change is usually thought of as passive, particularly when the individual is fatigued. Jones (1979) however takes the view that such changes are caused by conscious or unconscious shortening of muscles. Furthermore, postural changes are part of an active "total pattern" of responses and it is in this context that the startle pattern should be viewed. Building on the work of Magnus (1924,1925,1926a,1926b,1930), Jones suggests that the startle pattern is an example of the action of attitudinal head-neck reflexes. Although many different types of attitudinal reflexes are described in the literature, in the present context it is sufficient to state that in head-neck attitudinal reflexes the head is drawn into a fixed position. It is this position which imposes an attitude on the rest of the body by redistributing the muscle tone throughout the trunk and limbs. This allows the individual to maintain a position that is assumed for a particular purpose. It is postulated that the sitting or standing posture of the average human functions like an "attitude" which has been imposed on the body by the head. The startle pattern may then be viewed as a psycho-physical response to a fear or anxiety provoking stimulus.

Macdonald (1926) believed that the startle pattern had its biological basis in the several million years development of hominid bipedalism. When faced with danger or a quarry, the individual would tend to crouch rapidly to better escape detection. When the danger had passed the fixed position of the head would be released by means of the head righting reflex and move in such a way as to initiate the movement of the rest of the body towards its normal posture or attitude. The mismatch between the head and other body parts is registered at a postural centre in the brain which then initiates the righting response. As with the head-neck attitudinal reflex in posture and movement "the head leads and the body follows", restoring the normal distribution of muscle tone. This is most strikingly seen when a cat is held by its feet in the air and released; the head turns first, then the trunk and limbs, so that it lands on its feet. It should be made clear however that there are attitudinal and righting reflexes in other parts of the body which "lead" the rest of the body.

Eye, Labyrinth And Neck Reflexes

Labyrinth

Receptors in the inner ear (the labyrinth) respond to the positions and movements of the head and attempt to maintain the head in its normal attitude. A body falling accelerates towards the earth due to gravity. In response to this, signals from the labyrinths cause contraction of the leg extensors within 60-80 ms (Greenwood and Hokins,1976). Also, among many other effects they are linked to respiration as we will see later. They interact with the neck and other reflexes.

The method for preventing habitual postural preparations used in the present study was discovered by Alexander (1932). In his technique any unnecessary postural preparations of body parts are inhibited; then those postural preparations which prepare the body to move more efficiently are activated.

Neck

Some of the sensory mechanisms underlying these improvements are likely to be in the neck as well as in the rest of the proprioceptive system. The importance of the neck muscles in posture and movement has long been established (Longet 1845; Sherrington 1897; Magnus 1924).

Longet (1845) showed that surgical interference with the neck muscles produced generalised disturbances in posture and movement in a wide range of species. Sherrington (1897) established that neck receptors had a profound effect upon head posture, while Magnus (1924) went on to show that neck afferents can produce extensive changes in the whole body in association with the labyrinthine reflexes. Lindsey et al. (1976) suggested that the neck receptor system is as important as the labyrinths for controlling posture in cats.

Cervical ataxia has been produced in many species including man (Cohen 1961; De Jong et al. 1977; Lund 1980). DeJong et al. (1977) emphasises that this is not due to a loss of head motor control but is caused by a generalised disorder.

The receptors for this apparatus have been reported to be in the cervical vertebral joints (McCouch et al. 1951; Wyke 1979) but these studies have been heavily criticised (Abrahams 1982; Richmond and Bakker 1982). Other studies emphasise the receptors in the neck muscles (Cooper and Daniel 1963). Certainly the numbers and types of spindles present in neck muscles is impressive. In the cat, the lateral gastrocnemius contain 5 spindles per gram whereas in the neck muscles this ranges from about 100 per gram in large muscles to about 500 in the small ones (Bakker and Richmond 1982). In addition the spindles in the neck are in complexes suggesting a special role for the neck muscles (Richmond and Abrahams 1975).

It has long been accepted that the eye and labyrinth work closely together to maintain balance. The importance of the neck reflexes in normal humans was not widely accepted until recently, in spite of many studies showing that the neck musculature is critical for the control of posture and movement in animals and man (see discussion above). This appears to be due to Magnus's (1924) failure to find the same responses to neck movements in 26 normal infants that he had found in animal studies, only finding them in a brain damaged child, idiots and patients suffering from extra pyramidal tract lesions and other disorders of the central nervous system. He thus erroneously came to the conclusion that, in humans, the tonic neck reflex is a pathological phenomenon.

There are however many early studies reporting the elicitation of tonic neck reflexes. Mittelman (1922) was the first to show that muscle tone in the limbs could be changed by head movements in normal adults. Gesell (1938) pointed out that Magnus's conclusion was somewhat surprising since he and his co-workers found the tonic neck response a ubiquitous, indeed a dominating characteristic of normal infancy during the first three months of life.

Other workers reporting tonic neck reflexes in early brain development were Minkovski (1923) in the 3-5 month old foetus, Schaltenbrand (1925) in infants under 1 year and Simons (1923) in patients with cerebral shot wounds. Ikai (1950) reported that Sassa (1929) and Kono (1934) tried to examine the existence and regularity of this reflex by measuring the resistance of the limb musculature in healthy subjects, Parkinson patients and those suffering from hemiplegia. Although they observed changes in the resistance effected by postural change of the head, all the cases did not conform to the rules suggested by Magnus and de Klein (1912,1913).

Others reported by Ikai (1950) to have found the existence of the response in healthy human subjects include Goldstein and Riese (1923), Hoff and Schilder (1927) and Yokosuka (1926), the latter also found discrepancies between the direction of his subjects' responses and those of Magnus and de Klein. This early work on normal humans was later confirmed and extended by Fukuda (1943,1961), Wells (1944), Ikai (1944,1950), and Hellebrandt (1956,1962).

The differences observed between the various workers may in part be due to lack of control for labyrinth effects. More recently Lindsay et al. (1976) have re investigated the reports of Magnus and de Klein (1912) regarding positional reflexes of the labyrinths upon the limbs. Contrary to the lather's findings of symmetrical changes of tone for all head positions, Lindsay et al. (1976) observed that when the neck-head connections are severed and the head alone is rotated, asymmetric limb responses are obtained in which downhill limbs extend and uphill limbs flex, thus working in the opposite sense to the neck reflexes and not summating as suggested by Magnus (1925).

As Roberts (1978) comments, why it was that Magnus saw and described a symmetrical pattern remains a mystery.

Further evidence for the role of neck reflexes in controlling the limbs has been presented by Aiello, Rosati, Sau, Patraskakis, Bissakou and Traccis (1988), Traccis, Rosati, Patraskakis, Bissakou, Sau and Aiello (1987) and Rossi, Mazzocchio and Nuti (1986). In all of these studies tonic neck reflexes were shown to influence limb musculature in normal adult humans, providing a more rigorous confirmation of the existence of such effects, shown rather less quantitatively and without controls for labyrinthine influences, by Hellebrandt et al. (1962).

The study by Hellebrandt et al. (1962) can be criticised for not isolating neck reflexes, as in each test the head was moved to a different position in order to bend the neck, consequently labyrinthine effects cannot be excluded. However Ikai (1950), who also moved the head in his studies, investigated both normal subjects and deaf mutes, who demonstrated abolished labyrinthine function. As he could find no differences between the two sets of responses, he considered his tests were free of labyrinthine effects.

In an attempt to maintain head position whilst bending the neck, Rossi et al. (1986) had their subjects lying supine on a tilting table, the head was fixed in the horizontal plane in line with the body on an independent rigid frame. In this way they recorded the H-reflex from the soleus and concluded that neck ventroflexion exerted inhibitory influences on lower limb extensor motor neurones. This is in contrast to the findings of Hellebrandt et al. (1962), and of Jones and Kennedy (1951). However this may be explained by the observations of Huxley (1913) on the effects of head position and neck flexions in the duck. In this study Huxley observed that respiratory changes were dependent on head orientation, even when neck movements were identical. Thus the findings of Rossi et al. (1986) may not be relevant with respect to normal human head position.

In Jones and Kennedy (1951) startle pattern study, the head stayed at the normal angle to the vertical and is therefore only dorsiflexed relative to the neck, with the legs flexed. A later force platform study however found that the legs initially extended, then flexed (Jones 1979). The observations of Rossi et al. (1986) are in line with those of Fukuda (1961) who reported that all limbs flexed with head ventroflexion. The disparities in observations between these various studies can possibly be accounted for, as indicated earlier; however it is also possible that other reflexes exist; or indeed another type of reaction, as proposed by Roberts (1975).

Other Reflex Considerations

Neck proprioceptors have been shown to influence optic reflexes in rabbits by Hinoki, Hine, Okada, Ishida, Koike and Shizuku (1975). Huxley (1913), as mentioned above, showed they affected respiration in the duck.

The mechanisms underlying the reduction in blood pressure seen in the Alexander Technique may be connected with postural reflexes. Studies of tonic neck reflexes in normal human subjects has shown that dorsiflexion of the neck is associated with elbow extension (Hellebrandt et al 1962; Jones et al. 1964). As the Alexander Technique inhibits undue dorsiflexion (Jones 1965), which has been shown to be prevalent in humans under stress (Barlow 1973; Jones and Kennedy, 1951), it is reasonable to suggest that this would lessen the tendency towards dorsiflexion in these subjects and thus lower EMG activity in the triceps.

It has been shown (Fallentin, Sidenius and Jørgensen 1985) that prolonged low level contraction of the triceps muscle (1 hour at 7% MVC) produces a significant increase in arterial blood pressure from 104+/-10 to 120+/-12mm Hg, without any significant change in heart rate. As professional musicians can be required to hold an instrument whilst under stress for periods exceeding one hour, the arm muscles will be active for prolonged periods. It may be that the Alexander Technique facilitates appropriate postural reflexes and movement by modifying postural preparations. This would help in reducing inappropriate muscular contractions in any movement. This in turn could lead to a reduction in the increase of blood pressure due to performance anxiety.

In humans, as in other mammals the centre of gravity of the head lies in front of the atlanto-occipital joint. The weight of the head thus tends to stretch the postvertebral muscles and ligaments. Such stretching causes, in the cat at least, reflex excitation to motor neurones serving the hind limb extensors (Murthy et al. 1978). This supports Hellebrandt's earlier study in humans, albeit in the quadruped position. Returning the head towards its normal position can be seen to operate via the neck reflexes in order to restore the individual to the normal upright posture.

However, it would appear that postures like that of the startle pattern have become prevalent in most modern societies, as noted by Dart (1947) amongst others. These kinds of habitual postures are ill-adapted for movement, causing loss in height, as shown in the startle pattern and slump, together with narrowing of the chest and shoulders, twisting of the trunk and changes in the limbs.

Habitual twisting of the trunk and neck tend to be associated with lateral spinal curvatures which cause the spine to rotate (Lovett, 1903). Such induced scoliosis with its associated rotation may account for some of the contradictory findings of the effects of bending the head sideways on tonic neck reflexes. Fukuda (1961), for example, comments that in lateral head bending, the reflex pattern is not so clearly manifested as in the case of head rotation. In humans the extension and flexion of the four limbs sometimes occurs in reverse mode. A further effect on movements may be due to the fixed lateral curve interfering with the ability of the spine to rotate freely about its axis in the way proposed by Gracovetsky (1988), discussed earlier.

Nystagmus was inactive in many vertigo cases with whiplash injury studied by Hinoki, Hine and Tada (1971). These subjects showed abnormal neck EMGs and complained of neck pain. When the neck was fixed with a collar, nystagmus developed alongside reductions in the EMG activity. Similarly whiplash injury with hypertonicity in the cervical erector spinae muscles can cause vertigo due to over excitement of the beta receptors of the injured muscles (Hinoki and Niki 1975). These two findings may be regarded as representing the opposite of Alexander lessons with regard to the neck muscles.

The interaction of posture, physical disease, balance and circulation is highlighted by Sandström (1962) in a study of the effects of damage to the cervical spine. Patients with cervical syndrome have headaches, nausea, giddiness and develop uncertainty. One patient, for example, said that he felt as if he were permanently on board ship in a slightly rolling sea. The cause of the syndrome is thought to be an intermittent mild cerebral ischaemia in the distribution area of the vertebral artery.

The ischaemia is caused by pathological changes in the cervical spine, particularly osteochondrosis, which on head rotation compresses the vertebral artery and also possibly causes sympathetically - provoked contraction, due to irritation of the vertebral sympathetic nerve plexus surrounding the artery. Sandström (1962) suggested that the chief factor underlying susceptibility was a deficient collateral supply in the area supplied by the vertebral and basilar arteries. As the Alexander Technique has been shown to increase disc height in the cervical spine (Jones and Gilley 1960), it is possible that the vertebral arteries become less kinked thus making the brain less susceptible to compression induced ischaemia.

Other Proprioceptive Factors

Other proprioceptive factors are probably of importance, not just those in the neck. In Alexander's own case he reports that he had voluntarily made his legs and feet too tense and that this was involved in the problems he had with head balance, his voice and breathing. He reports that the shortening of the toe flexors was such that arches of his feet were grossly exaggerated and his balance was disturbed (Alexander 1932).

Stretch of the interosseus muscles of the foot are important in the positive supporting reactions in the legs (Roberts 1978). It is also worth recalling here that Orma (1957) reported the importance of foot and ankle proprioception and Lund and Broberg's (1983) findings on the role of the knee and hip in balance.

According to Hinoki and Ushio (1975) lumbomuscular proprioception plays an important role in posture. They showed that lumbar muscle pain, vertigo, nystagmus, with impaired righting reflexes and gait, are all induced by injecting the lumbar erector spinae muscles in healthy subjects with procaine, a local anaesthetic. The opposite was found in patients suffering from whiplash injury induced vertigo, who suffered from lumbosacral pain when the painful area was procainized. In this case there were reductions in their lumbar muscle pain, vertigo, nystagmus, with improvements in their righting reflexes and gait. Trunk proprioceptors have also been implicated in the control of the orientation of postural sway (Lund and Broberg 1983).

Generally proprioception has a vital, if mild, role in the stabilisation of self generated motor output in postural states. Specifically, maintaining a constant position or force, even in the absence of external perturbations, cannot be performed adequately without input from muscle afferents. (Hasan and Stuart 1988)

Sacks (1986) reports on the psychological as well as physical effects of general proprioceptive loss. It would appear that not only does proprioception respond to the physical actions of the organism but that it is central to our conscious psychological sense of identity.

Narrowing of the chest and shoulders may adversely affect the supporting reactions, as shown in cats by D'Ascanio, Gahery, Pompeiano and Stampacchia (1986) and Gahery and Pompeiano (1986). Their experiments showed that postural and motor deficits involving the neck and limb extensor musculature were caused by pressure applied to the body surface. Although they were of the opinion that the effects were due to touch only, it can be argued that the applied pressures could produce proprioceptive effects (McClosky 1978).

In particular when elastic bands were crossed over the chest, the tonic contraction of the extensor limb and trunk musculature decreased in the animal at rest. Moreover the positive supporting reaction as well as the myotatic reflexes observed after passive flexion of the limbs were both depressed. These postural and reflex deficits were also associated with disequilibrium and abnormalities in movement during locomotion, so that the animal behaved as if it were affected by a vestibular syndrome.

These are comparable with pictures produced by Frank (1938) on the effects of pulling babies by their hands into a sitting position, and those of the startle pattern produced by Jones, Hansen and Gray (1964). In both cases the shoulders and upper chest are narrowed. Both studies also suggest a general shortening of the trunk.

The interaction between limb and trunk extension is also found in the reverse direction. That is, the development of a supporting reaction in the legs produces a stiffening and straightening of the back. Additionally, in the dog, extension at the hip joint causes the forelimbs and back to be extended even when the forelimbs are not in contact with the ground (Rademaker 1931; Roberts 1978). Conversely if the supporting reaction is not developed, as shown by Frank (1938) in babies or by Rademaker (1931) in dogs, the back cannot support the body and buckles.

As well as the interplay of the legs with each other and with the trunk, individual joints in a limb may have strong effects. As mentioned earlier, the positive supporting reaction is developed when the digits are splayed due to pressure on the sole of the foot. If the phalanges are flexed or squeezed laterally together, all the joints of the limb (in the case of a dog) are thrown into active flexion and the limb is unable to support weight (Roberts, 1978). This response is sometimes called the negative supporting reaction. Although not manifest in humans it may, like the neck reflexes, be latent (Fukuda 1961).

In general it would appear that shortening of postural muscles and a reduction in proprioceptive information are related to a reduced ability to respond fully to the requirements of effectively operating in the gravitational field. It may be that the mechanisms so far considered are components of some other more general patterns, as will be discussed later.

It is proposed that proprioceptive acuity will be lower in shortened muscles than in those under stretch, as well as being inaccurate in overstretched connective tissue as noted earlier. Indeed for relatively fast movements in man the reflex responsiveness of a shortening muscle is depressed (Gottlieb and Agarwal 1980,1984).

Hasan and Stuart (1988) believe that a passively stretched antagonistic muscle is more likely to give information in absolute terms about the kinematic state of the joint than the agonist. This seems to directly relate to Alexander's experiences that he did not perceive accurately the effects of the various contractions referred to earlier.

If attitudinal reflexes are prolonged, muscles will be held in fixed positions under their influence. According to Magnus (1925,1926) these are the most enduring and untiring of reflexes. The prolonged holding of inappropriate attitudinally induced postures could have mechanical effects on elastic tissues, considered earlier, perhaps causing the postural deterioration observed by Asmussen (1960). These will tend to fix the attitude and thus perpetuate the inappropriate response. The loss of proprioceptive acuity postulated earlier prevents the individual being alerted to what is taking place.

As mentioned earlier it may be that the startle pattern can, with fatigue or boredom, and psychological depression, become a slump. With low muscle tone, but still with an apparently attitudinally imposed body posture, it may not be different in kind from the startle pattern, merely a

chronic low level continuation of it. The lack of muscle tone and proprioceptive information being now due to lower levels of cortical activity, as the stretch reflex requires cortical arousal to activate the gamma fusimotor neurones (Brooks 1986).

Whether such factors are involved in pain has been raised in a study of pain management by Fisher (1988). In this the perceived value of 13 different pain reduction activities by subjects in a pain management programme were collected at the end of the course, 3 months and 1 year later. In each case the Alexander Technique received the highest rating.

Conclusions

A series of experiments have been designed to measure some of the physical changes found by Alexander and others as well as to elucidate, if possible, the mechanisms underlying the Alexander Technique. By reference to the literature some suggestions for the mechanisms responsible have been made. This and other studies suggest that the Alexander Technique can be learned.

In summary the method of the Technique and its results are as follows: It has as its first action a reorientation of attention to recognise inappropriate postural preparations and then to inhibit them. By then selecting and activating a more appropriate pattern of postural preparations, it appears to progressively release the body from habitual attitudes, perhaps by facilitating righting reflexes. This in turn starts the process of bringing the body into a natural upright posture characterised by greater height, greater shoulder and chest width, and better balance. Also noted are faster and less effortful movement patterns, improved responses to stress, greater respiratory, circulatory and digestive efficiency, and improvements in performance. It appears to improve proprioceptive acuity thus aiding the learning of skills.

Learning to allow postural reflexes to operate advantageously during movement may be a component of lessons in the Alexander Technique. It is argued that in this way the skill of using the body in a more coordinated way can be developed. Above all, this skill appears to depend on being fully alert (Ballard 1988).

It is possible that the Alexander Technique involves reflexes and other response patterns not previously recognised; firstly a "general shortening response" like a chronically maintained startle pattern, connected with fear and the need for concealment; and secondly a "general lengthening response" which produces an integrated response to gravity and the requirements of rapid and powerful movements being carried out with the greatest efficiency, involving an optimal operation of the sensory, nervous and visceral systems. It would also appear that both these postulated responses involve the postural reflexes in all segments of the body. It would appear that preventing the inappropriate use of the "general shortening response" and establishing the "general lengthening response" as the norm gives a sound biological basis for a more effective performance of the many interpersonal, social, cultural and other aspects of human life we can choose to carry out under civilised conditions.

Alexander made his discovery empirically, and this is the dominant teaching style today. However it is now possible to make improvements in the practice and teaching of the Technique by applying more fully the discoveries in relevant scientific fields, such as those detailed in this report.

References

Abrahams VC (1977) The physiology of neck muscles; their role in head movement and maintenance of posture. Can J Physiol Pharmacol 55:332-338

Abrahams VC (1982) Neck muscle proprioception and motor control. In: Garlick D (Ed) Proprioception, Posture and Emotion, Committee for Postgraduate Education, University of NSW, Australia

Abrahams VC, Falchetto S (1969) Hindlimb ataxia of cervical origin and cervico-lumbar interactions with a supratectorial pathway. J Physiol 203:435-447

Adrien ED, Matthews BHC (1934) The Berger rhythm: potential changes from the occipital lobes of man. Brain 57:355-384

Aiello I, Rosati G, Sau GF, Patraskakis S, Bissakou M, Traccis S (1988) Tonic neck reflexes on upper limb flexor tone in man. Expl Neurol 101: 41-49

Alexander FM (1932) The Use of the Self, Methuen, London Republished 1985 Gollancz, London.

Alexander RMcN (1986) Making headway in Africa. Nature 319:623-4

Alexander RMcN (1987) The spring in your step. New Scientist 114/1558: 42-44.

Alexander RMcN, Bennet-Clark HC (1977) Storage of elastic strain energy in muscle and other tissues. Nature 265:114-117.

Alexander RMcN, Dimery NJD, Ker RF (1985) Elastic structures in the back and their role in galloping in some animals. J Zool Lond (A) 207: 467-482

Asmussen E (1960) The weight bearing function of the human spine. Acta Orthop Scand 29: 276-290

Asmussen E, Klausen K (1962) Form and function of the erect human spine. Clin Orthop Rel Res 25: 55-63

Austin JH, Ausubel P (1992) Enhanced respiratory muscular function in normal adults after lessons in proprioceptive education without exercises. Chest 102: 486-90.

Austin JH, Pullin GS (1984) Improved respiratory function after lessons in the Alexander Technique of musculoskeletal education. Am Rev Resp Dis 129-2: 275

Baid T, Kralj A, Turk R (1982) Standing up of a healthy subject and a paraplegic patient. J Biomech 15:1-10
Bakker DA, Richmond FJR (1982) Muscle spindle complexes in muscles around upper cervical vertebrae in the cat. J Neurophysiol 48:62-74

Ballard KJ (1977) Typical sympathetic noradrenergic endings in a muscle spindle of the cat. J Physiol 285: 61-62

Ballard KJ (1988) in Stevens CH (Ed) (1988, 1994) The Alexander Technique: Medical and Physiological Aspects, Folkeuniversitet, Aalborg, Denmark

Barlow W (1946) An investigation into kinaesthesia. Medical Press Circular 215: 60-63

Barlow W (1947) Anxiety and muscle tension. Br J Phys Med 10: 1-7

Barlow W (1952) Postural homeostasis. Ann Phys Med 1: 77-89

Barlow W (1954) Posture and the resting state. Ann Phys Med 2: 113-122

Barlow W (1955) Psychosomatic problems in postural re-education. The Lancet Sept. 24, 659-664.

Barlow W. (1956) Postural deformity. Proc Roy Soc Med 49: 670-674

Barlow W (1959) Anxiety and muscle tension pain. Br J Clin Pract 13: 339-350

Barlow W (1964) Rest and pain. Exe Med Int Series 107: 494-498

Barlow W (1973) The Alexander Principle, Golancz, London

Basmajian JV, de Luca CJ (1985) Muscles Alive, Williams and Wilkins, Baltimore

Becker W, Iwase K, Jürgens R, Kornhuber HH: (1976) Brain potentials preceding slow and rapid hand movements. In The Responsive Brain. Mc Cullum, Knott (eds.) Wright, Bristol

Belenkii VYe, Gurfinkel VS, Paltsev YeI (1967) Elements in control of voluntary movements. Biophysics 12:263-270

Black FO, Wall III C, Nashner LM (1983) Effect of visual and support surface orientation references upon postural control in vestibular deficient subjects. Acta Otolaryngol 95: 199-210

Bouisset S, Zattara M (1981) A sequence of postural movements precedes voluntary movement. Neurosci Lett 22:263-270

Bojsen-Møller F (1987) Functional anatomy of the connective tissue structures of the lower extremity. Procs 2nd Scand Con on Sports Medicine, Oslo, Norway 153-160

Bojsen-Møller F (1988) in Stevens CH (Ed) (1988, 1994) The Alexander Technique: Medical and Physiological Aspects, Folkeuniversitet, Aalborg, Denmark

Bower B (1986) Who's the Boss? Sci. News 129: April 26; 266-267

Boyd IA (1980) The isolated mammalian muscle spindle. TINS 3: 258-265

Boyd IA (1986) Two types of static gamma-axon in cat muscle spindles. Q J Exp Physiol CMS 71: 307-327

Boyd IA, Gladden MH (1985) (Eds.) The Muscle Spindle, Macmillan Press, London.

Brooks VB (1986) The Neural Basis of Motor Control, Oxford University Press

Brown RA (1977) Kinaesthetic and cognitive determinants of emotional state: an investigation of the Alexander Technique. Ph.D. dissertation, Tufts University, USA..

Bruce BP, Caldwell JR, Dick JH, Douglas M, Duffett H, Ensor CA, Graham WJ, Gunn AR, Jakins P, Kerr J, Ligat D, McDonagh JE, Macdonald P, McGowan RG, Moss A, Murdoch A, Thorne FJ, Webb H, Winchester AH (1937) Constructive conscious control (letter), British

Med J. 1: 1137

Burke D (1980) Muscle spindle function during movement. TINS 3: 251-253.

Burke D, Mckeon B, Skuse NF, Westerman RA (1980) Anticipation and fusimotor activity in preparation for a voluntary contraction. J Physiol 306: 337-348

Burke RE, Rudomin P, Zajac FE (1970) Catch property of single mammalian motor units. Science 168: 139-143

Butler DL, Grood ES, Noyes FR, Zernicke RF (1978) Biomechanics of ligaments and tendons. Ex Sports Sci Rev 6: 125-182

Cavagna GA, Komarekko L, Mazzolen S (1971) The mechanics of sprint running. J Physiol 207: 467-482

Christiansen AF, Kardorf U, Bojsen-Møller F (1982) Concentric and eccentric concentractions of hip and trunk muscles while seating oneself and rising. Zdvar Vestn (suppl 1) 51: 41-42

Clark RD, Lord SR, Webster IW (1993) Clinical parameters associated with falls in an elderly population. Gerontol 39: 117-123

Close RI (1972) Dynamic properties of mammalian skeletal muscles Physiol Rev 52: 129

Coghill JE (1942) Appreciation: the Educational Methods of F. M. Alexander, in Alexander F.M. The Universal Constant in Living (reprinted 1987) Centerline Press, Downey, CA

Cohen LA (1961) Role of eye and neck proprioceptive mechanisms in body orientation and motor coordination. J Neurophysiol 24:1-11

Collins P (1987) in Stevens CH (1987, 1993, 1995) Alexander Technique, Vermilion, London

Collins R, Petro R, Mac Mahon S, Herbert P, Fiebach NH, Eberlein KA, Qizilbash N, Taylor JO, Hennekens CH (1990) Blood pressure, stroke and coronary heart disease, Part II: Effects of short-term reductions in blood pressure - An overview of randomized drug trials in an epidemiological context. Lancet 335: 827-838

Cooper S, Daniel PM (1963) Muscle spindles in man; their morphology in the lumbricals and the deep muscles of the neck. Brain 86:563-594

Curtin NA, Davies RE (1972) Chemical and mechanical changes during stretching of activated frog skeletal muscle. Cold Spring Harbour Symp Quant Biol 37: 619-626

Dart RA (1947) The attainment of poise. SA Med J 21: 74-91

Dart RA (1970) An anatomists tribute to F. M. Alexander. Sheildrake Press, London.

D'Ascanio P, Gahery Y, Pompeiano O, Stampacchia G (1986) Effects of pressure stimulation of the body surface on posture and vestibulospinal reflexes. Arch Ital Biol 124: 43-63

de Jong PT, de Jong JM, Cohen B (1977) Ataxia and nystagmus induced by injection of local anaesthetics in the neck. Ann Neurol 1:240-246

DePuky P (1935) The physiological oscillation in the length of the spine. Acta Orthop Scand 6: 338-347

Desmedt JE, Robertson D (1977) Search for right hemisphere asymmetries in event related potentials to somatosesory cueing signals. In Language and Hemispheric Specialisation in Man : cerebral event related potentials. Desmedt JE (Ed,) Karger, Basel 172-187

Djupsjöbacka M (1994) Regulation of the gamma-muscle-spindle system by chemosensitive muscle afferents and joint afferents. Umeå University Medical Dissertation

Doyle J. (1984) The task of the violinist: skill, stress and the Alexander

Technique. Ph.D. thesis, University of Lancaster, England

Edgerton VR, Smith JL, Simpson DR (1975) Muscle fibre type populations of human leg muscles. Histochem J 7: 259-266

Era P, Heikkinen E (1985) Postural sway during standing and unexpected disturbances of balance in random samples of men of different ages. J Geront 40: 287-295

Evatt ML, Wolf SL, Segal RL (1989) Modification of human spinal stretch reflex: preliminary studies. Neuroscience Letters 105, 350-355

Fallentin N, Sidenius B, Jørgensen K (1985) Blood pressure, heart rate and EMG in low level static contractions. Acta Physiol Scand 125: 265-275

Fearing FS (1924) The factors that influence static equilibrium. J Comp Psychol 4: 162-183

Feuerstein M, Labbe EE, Kuczmierczyk AR (1986) Health psychology a psychobiological perspective. Plenum Press, New York and London

Fisher K (1988) Early experiences of a multidisciplinary pain management programme. Holistic Med 3: 47-56

Frank A (1938) A study in infant development. Child Dev 9: 9-26

Fukuda T (1943) Zibiinkoka-Rinsyo (Japanese) 39:1

Fukuda T (1961) Studies of human dynamic postures from the viewpoint of postural reflexes. Acta Otolaryngol Suppl 161:6-51

Gahery Y (1987) Associated movements, postural adjustments and synergy: some comments about the history and significance of three motor concepts. Arch Ital Biol 125: 345-360

Gahery Y, Massion J (1981) Coordination between posture and movement. TINS 4:199-202

Gahery Y, Pompeiano O. (1986) Effects of pressure stimulation of the body surface on placing reactions. Arch Ital Biol 124: 65-72

Garlick D (1986) A physiologist looks at the Alexander Technique. The Alexander Review 1: 2-6

Garlick D (1988) Personal communication with the author

Gesell A (1938) The tonic neck reflex in the human infant. J Pediat 13: 455-464

Goldstein K, Riese W (1923) Klin Wochenschr 2:1201

Goldthwait JE, Brown LT, Swaims LT, Kuhns JG, Kerr WJ (1941) Body Mechanics in Health and Disease 3rd ed., Lippincott, Philadelphia

Goode DJ, van Hoven J (1982) Tendon reflexes in classical ballet dancers. Archives of Neurology 39, 323

Gordon AM, Huxley AF, Julian FJ (1966) The variation in isometric tension with sarcomere length in vertebrate muscle fibres. J Physiol 184: 170-192

Gottlieb GL, Agarwal GC (1980) Response to sudden torque about the ankle in man. J Neurophysiol 44: 233-246

Gottlieb GL, Agarwal GC (1984) Modulation of human spinal reflexes. In: Brainstem Control of Spinal Cord Function, ed. C.D. Barnes, Academic Press, Orlando

Gracovetsky S (1988) The Spinal Engine, Springer, Wien

Grassi C, Filippi GM, Passatore M (1987) Brain Research 435: 15-23

Greenwood R, Hopkins A (1976) Muscle response during sudden falls in man. J Physiol 254: 507-18

Hasan Z, Stuart DG (1988) Animal solutions to problems of movement control. Ann Rev Neurosci 11: 199-223

Heglund NC, Willems PA, Penta M, Cavagna GA (1995) Energy-saving gait mechanics with head-supported loads. Nature 375: 52-54

Hellebrandt FA, Houtz SJ, Partridge MJ, Walters CE (1956) Tonic neck reflexes in exercises of stress in man. Am J Phys Med 35: 144-159

Hellebrandt FA, Schade M, Carns ML (1962) Methods of evoking the tonic neck reflexes in normal human subjects. Am J Phys Med 41: 90-139

Hennekens CH, Burling J (1993) Observational evidence. In Warren KS and Mosteller F (Eds) Doing More Good Than Harm, annals of the New York Academy of Sciences vol. 703, New York

Hill AV (1953) The mechanics of active muscle. Proc Roy Soc B 141: 104-117

Hinoki M, Hine S, Okada S, Ishida Y, Koike S, Shizuku S (1985) Optic organ and cervical proprioceptors in maintenance of body equilibrium. Acta Otolaryngol Suppl 330: 169-184

Hinoki M, Hine S, Tada Y (1971) Neurological studies on vertigo due to whiplash injury. Equil Res Suppl 1: 3

Hinoki M, Niki H (1975) Neurological studies on the role of the sympathetic nervous system in the formation of traumatic vertigo of cervical origin. Acta Otolaryngol Suppl 330: 185-196

Hinoki M, Ushio N (1975) Lumbomuscular proprioceptive reflexes in body equilibrium. Acta Otolaryngol Suppl 330: 197-210

Hlavacka F, Krizkova M (1979) Importance of information content of visual feedback in upright posture in man. Act Nerv Sup (Praha) 21: 30-32

Hof AL, Geelen BA, van den Berg JW (1983) Calf muscle movement,

work and efficiency in level walking; role of series elasticity. J Biomech 16: 523-537

Hoff H, Schider P (1927) Die Lagereflexe des Menscen, Springer, Wien

Hunt CC, Jami L, Laporte Y (1982) Effects of stimulating the lumbar sympathetic trunk on cat hindlimb sympathetic spindles Archives Italiennes de Biol 120, 371-384

Huxley FM (1913) On the reflex nature of apnoea in the duck in diving. Quart J Expt Physiol 6: 147-196

Ikai M (1944) Nihonseirigaku-Zassi (Japanese) 9:654

Ikai M (1950) Tonic neck reflex in normal persons. Jap J Physiol 1: 118-124

Ingvar DH (1975) Patterns of brain activity revealed by measurements of regional cerebral blood flow. In Brain Work, Ingvar DH, Lassen NA (eds) 397-413, Munksgaard, Copenhagen

James IM, Burgoyne W, Savage IT (1983) Effect of pindolol on stress related disturbances of musical performance. J Roy Soc Med 76: l94-196

James IM, Griffith DNW, Pearson RM, Newbury P (1977) Effect of exprenolol on stage-fright in musicians. Lancet ii: 952-4

Johansson H, Djupsjöbacka M, Sjölander P (1993) Influences on the gamma-muscle-spindle system from muscle afferents stimulated by KCl and lactic acid. Neuroscience Research 16, 49-57

Johansson H, Sjölander P, Sojla P (1991) Fusimotor reflex profiles of individual triceps surae primary muscle spindle afferents assessed with multi-afferent recording technique. J de Physiologie (Paris) 85, 6-19

Johansson H, Sojka P (1991) Pathophysiological mechanisms involved in genesis and spread of muscular tension in occupational muscle pain and in chronic musculoskeletal pain syndromes: an hypothesis. Medical

Hypotheses 35, 196-203

Jones FP (1963) The influence of postural set on pattern of movement in man. Int J Neurol 4: 60-7l

Jones FP (1965) Method for changing stereotyped response patterns by the inhibition of certain postural sets. Psychol Rev 72: 196-214

Jones FP (1971) An experimental study of the Alexander Technique. Stud Med (Copenhagen) 35:2-5

Jones FP (1972) Voice production as a function of head balance in singers. J Psychol 82: 209-215

Jones FP (1979) Body Awareness in Action: A study of the Alexander Technique, Schocken, New York

Jones FP, Gilley PFM (1960) Head balance and sitting posture: an x-ray analysis. J Psychol 49: 289-293

Jones FP, Gray FE, Hanson JA, O'Connell DN (1959) An experimental study of the effect of head balance on patterns of posture and movement in man. J Psychol 47: 247-258

Jones FP, Hanson JA (1961) Time-space pattern in a gross body movement. Percept Motor Skills 12: 35-41

Jones FP, Hanson JA (1962) Note on the persistence of pattern in a gross body movement. Percept Motor Skills 14: 230

Jones FP, Hansen JA (1970) Posture Set and overt movement: a force platform analysis. Percept Motor Skills 30: 699-702

Jones FP, Hansen JA, Gray FE (1961) Head balance and sitting posture II: The role of the sternomastoid muscle. J. Psychol 52: 363-7

Jones FP, Hanson JA, Gray FE (1964) Startle as a paradigm of malposture. Percept Motor Skills 19: 21-22

Jones FP, Hanson JA, Miller JK, Bossom J (1963) Quantitative analysis of abnormal movement: the sit to stand pattern. Am J Phys Med 42: 208-218

Jones FP, Kennedy JL (1951) An electromyographic technique for recording the startle pattern. J Psychol 32: 63-8

Joyce GC, Rack PMH, Westbury DR (1969) The mechanical properties of cat soleus muscle during controlled lengthening and shortening movements. J Physiol 204: 461-474

Kilbom Å, Persson J (1987) Work technique and its consequences for musculoskeletal disorders. Ergonomics 30, 273-279

Kono H (1934) Tokyo-Igakkai-Zassi (Japanese). 48: 654

Kornhuber HH, Deeke L (1964) Hirnpotentialänderungen beim Menschen vor und nach Willkürbewegunen dargestellt mit Magnerbandspeicherung und Rückwärtsanalyse. Pflügers Arch. Ges. Physiol. 281: 52

Landis C, Hunt W (1939) The Startle Pattern, Farrar and Rinehart, New York

Lanshammer H (1982) On practical evaluation of differentiation techniques for human gait analysis. J Biomech 15: 99-105

Lassen NA, Ingvar DM, Skinhaaj E (1978) Patterns of activity in the human cerebral cortex graphically displayed. Sci Am 239/4: 50-59

Lee DN, Aronson E (1974) Visual proprioceptive control of standing in infants. Percep Psychophys 15: 529-532

Lewis MMcD, Porter R (1974) Pyramidal tract discharge in relation to movement performance in monkey with partial anaesthesia of the moving hand. Brain Res 71: 345-5l

Libet B (1982) Brain stimulation in the study of neuronal functions for conscious sensory experience. Human Neurobiol 1: 235-42

Libet B (1985) Unconscious cerebral initiative and the role of conscious will in voluntary action. Behav Brain Sci 8: 529-66

Libet B (1989) Personal correspondence with the author

Lindbeck L (1985) Analysis of functional scoliosis by means of an anisotropic beam model of the human spine. J Biomech Eng 107: 281-5

Lindsay KW, Roberts TD, Rosenberg JR (1976) Asymmetric tonic labyrinth reflexes and their interactions with neck reflexes in the decerebrate cat. J Physiol 261:583-601

Longet FA (1845) Sur les troubles qui serviennent dans lequilibrium, la station la locomotion des animaux, apres la section des parties molles de la nuque. Gaz Med (Paris) 13:565-567

Lovett AW (1903) A contribution to the study of the mechanics of the spine. Am J Anat 2: 457-462

Lucas DB, Bresler B (1961) Stability of the ligamentous spine. Technical Report ser. 11, no. 40. Biomechanics Laboratory U. of Calif, Berkeley and San Francisco

Lund S (1980) Postural effects of neck muscle vibration in man. Experientia 36:1398

Lund S, Broberg C (1983) The effects of different head positions on postural sway in man induced by a reproducible vestibular error signal. Acta Physiol Scand 117: 307-309

Lundberg A (1967) The supraspinal control of transmission in spinal reflex pathways. In: Widén L (Ed) Recent Advances on Clinical Neurophysiology. Electroenceph Clin Neurophysiol Suppl 25, Elsevier, Amsterdam 35-46

McCouch GP, Deering ID, Ling TH (1951) Location of receptors for tonic

neck reflexes. J Neurophysiol 14:191-195

McCloskey DI (1978) Kinaesthetic sensibility. Physiol Reviews 58: 763-820

Macdonald P (1926) Instinct and functioning in health and disease. Br Med J 2: 1221-1223

Magnus R (1924) Körperstellung, Springer, Berlin

Magnus R (1925) Animal posture. Proc Roy Soc Lond 98(B): 339-353

Magnus R (1926a) Some results of studies in the physiology of posture Part I. Lancet 211: 531-536

Magnus R (1926b) Some results of studies in the physiology of posture Part II. Lancet 211: 585-588

Magnus R (1930) The physiological a priori, Lane lectures on experimental pharmacology and medicine: III. Stanford University Publications Series V2 no.3: 331-337

Magnus R, de Kleijn A (1912) Die abhängigkeit des tonus der extremitatenmuskeln von der kopfstellung. Pflügers Archiv 145: 455-458

Magnus R, de Kleijn A (1913) Die abhängigkeit der körperstellung vom kopfstande beim normalen kaninchen. Pflügers Archiv 154: 163

Magnusson M, Enbon H, Johansson R, Pyykkö I (1990) Significance of pressor input from the human feet in anterior-posterior postural control. Acta Otolaryngol (Stockh) 110, 182-188

Maloiy GM, Heglund NC, Prager LM, Cavagna GA, Taylor CR (1986) Energetic cost of carrying loads: have African women discovered an economic way? Nature 319, 6055: 668-669

Massion J (1993) Feedforward control of posture and equilibrium during movement performance. In Electrophysiological Kinesiology, Pedotti A

(Ed.) IOS Press, Amsterdam

Minkowski M (1921) Sur les mouvements, les reflexes et les reactions musculaires du foetus humain de 2 a 5 mois et leur relations avec le system nerveux foetal. Rev neurol 37: 1105

Mittelmann B (1922) Über längeranhltende (tonische) beeinflussungen des kontraktionszustandes der skelettmuskulatur des menschen. Arch Ges Physiol 196: 531-539

Morris JM, Lucas DB, Bresler B (1961). Role of the trunk in stability of the spine. J Bone Joint Surg 43A: 327-51

Murthy KSK, Gildenberg PL, Marchand JE (1978) Descending long spinal excitation of lumbar alpha and gamma motoneurones evoked by stretch of dorsal neck muscles. Brain Res 140: 165-170

Nachemson A (1976) The lumbar spine: an orthopaedic challenge. Spine 1: 59-71

Nachemson A (1981) Disc pressure measurements. Spine 6:93-97

Odenrick P, Sandsted P (1984) Development of postural sway in the normal child. Human Neurobiol 3: 241-244

Orma EJ (1957) Effects of cooling the feet and closing the eyes on standing equilibrium: different patterns of standing equilibrium in young adult men and women. Acta Physiol Scand 23: 288-297

Overstall PW, Exton-Smith AN, Imms FJ, Johnson AL (1977) Falls in the elderly related to postural inbalance. Br Med J 1: 261-264

Passatore M, Grassi C, Fillipiti GM (1985) Sympathetically induced development of tension in jaw muscles: the possible contraction of intrafusal muscle fibres. Pflügers Archiv 405, 297-304

Payne H (1968) How I improved this year. Athletics Weekly, Nov. 30th. 18-20

Priest J (1984) Posture and Pain, (video) Central Office of Information, London

Rademaker GGJ (1931) Das stehen, statische reaktionen, gleichgewichtstreaktionen und muskeltonus unter besonderer berüksichtigung ihres verhaltens bei kleinhirnlosen tieren. Springer, Berlin

Raine S, Garlick D (1986) Postural analyses of standing human subjects, Abstract, 21st Ann Conf Anat Soc Aus + NZ, Brisbane

Ribot E, Roll J, Veedel J (1986) Efferent discharges recorded from single skeletomotor and fusimotor fibres in man. J Physiol (Lond) 375, 251-268

Richmond FJR, Abrahams VC (1975) Morphology and distribution of muscle spindles in dorsal muscles of the cat neck. J Neurophysiol 38:1322-1329

Richmond FJR, Bakker DA (1982) Anatomical organisation and sensory receptor content of soft tissues surrounding upper cervical vertebrae in the cat. J Neurophysiol 48:49-61

Roberts TDM (1973) Reflex balance. Nature 244: 156-158

Roberts TDM (1975) Reflex contributions to the assessment of the vertical. Acta Astronaut 2: 59-67

Roberts TDM (1978) Neurophysiology of Postural Mechanisms (2nd Ed.), Butterworths, London

Robinson L, Garlick D (1985) Comparison of respiratory movements and frequencies in normal and trained subjects. Proc Aus Physiol Pharm Soc 16: 256

Roland P (1981) Somatotopical training of postcentral gyrus during focal attention in man. A regional cerebral blood flow study. J Neurophysiol 46: 744-54

Roland PE, Larsen B, Lassen NA, Skinhøj E (1980) Supplementary motor area and other cortical areas in organisation of voluntary movements in man. J Neurophysiol 43: 118-36

Rossi A, Mazzocchio R, Nuti D (1986) Tonic neck influences on lower limb extensor motor neurones in man. Electromyogr clin Neurophysiol 26: 207-216

Rotto DM, Kaufman MP (1988) Effect of metabolic products of muscular contraction on discharge of group III and IV afferents. J Applied Physiol 64, 2306-2313

Sacks O (1986) The Man Who Mistook His Wife for a Hat, Paladin. London

Sandström J (1962) Cervical syndrome with vestibular symptoms. Acta otolaryngol 54: 207-227

Sassa K (1929) Sinkeigakkai-Zassi (Japanese). 30: 433

Schalternbrand G (1925) Normal bewegungs und lagereaktionen bei kindern. Deutsche Ztschr Nervenh 84: 85-89

Schantz PG, Henriksson J (1983) Increases in myofibrillar ATPase intermediate in human skeletal muscle fibres in response to endurance training. Muscle Nerve 6, 553-556

Sherrington CS (1897) Decerebrate rigidity and reflex coordination of movement. J Physiol 22:319-332

Sherrington CS (1946) The Endeavour of Jean Fernel, Cambridge University Press

Simon J, Wei JY, Randic M, Burgess PR (1984) Signaling of ankle joint position by receptors in different muscles. Somatosens Res 2, 127-147

Simons A (1923) Kopfhaltung und muskeltonus. Ztschr ges Neurol Psychiat 80: 499

Simonsen EB, Edgerton VR, Bojsen-Møller F (1988) Energy restitution and power amplification in human plantaris tendons. Int Ser Biomech, Biomechanics XI-A

Soames RW, Atha J (1981) The Role of the antigravity musculature during quiet standing in man. Eur J Appl Physiol 47: 159-167

Stevens CH (1987, 1993, 1995) Alexander Technique, Vermilion, London

Stevens CH (Ed) (1988, 1994) The Alexander Technique: Medical and Physiological Aspects, Folkeuniversitet, Aalborg, Denmark

Stevens CH, Bojsen-Møller F, Soames RW (1989) Influence of initial posture on the sit-to-stand movement. Eur J Appl Physiol 58: 687-692

Tanner JM (1962) Growth at Adolescence, Oxford University Press, Oxford

Taylor CR (1995) Freeloading women. Nature 375: 17

Thortensson A, Carlson H, Zomlefer MR, Nilsson J (1982) Lumbar back muscle activity in relation to trunk movements during locomotion in man. Acta Physiol Scand 116: 13-20

Thortensson A, Carlson H (1987) Fibre types in human lumbar back muscles. Acta Physiol Scand 131: 195-202

Timoshenko SP (1961) Theory of Elastic Stability, McGraw Hill, New York

Tinbergen N (1974) Ethology and stress diseases. Science 185: 20-27

Tokita TM, Maeda M, Miuata H (1981) The role of the labyrinth in standing posture regulation. Acta Otolaryngol 91: 521-527

Traccis S, Rosati G, Patraskakis S, Bissakou M, Sau GF, Aiello I (1987) Influences of neck receptors on soleus motor neurone excitability in man.

Expt Neurol 95: 76-84

Veiersted KB, Westergaard RH (1993) Development of trapezius myalgia among female workers performing light manual work. Scandinavian J of Work Environment and Health 19, 277-283

Viidik A (1978) On the correlation between structure and mechanical function of soft connective tissue. Verhandlungen der Anatomischen Gesellschaft 72:75-89

Voutsinas SA, MacEwen GD (1986) Sagittal profiles of the spine. Clin Orthop Rel Res 210: 235-242

Wells HS (1944) The demonstration of tonic neck and labyrinthine reflexes and positive heliotropic responses in normal human subjects. Science 99: 36-37

Williams KR (1985) The relationship between mechanical and physiological energy estimates. Med Sci Sports Exer 17: 317-329

Wolpaw JR (1985) Adaptive plasticity in the spinal stretch reflex: an accessible substrate of memory? Cellular and Molecular Neurobiology 5, 147-165

Woodhull AM, Maltrud K, Mello BL (1985) Alignment of the human body in standing. Eur J Appl Physiol 54: 109-115

Wyke BD (1979) Neurology of cervical spinal joints. Physiotherapy 65:72-76

Yokosuka T (1926) Seisin-Sinkei-gakkai-Zassi (Japanese) 44: 550

Yoshida K, Iwakure H, Inoue F (1983) Motion analysis in the movements of standing up from sitting down on a chair. Scand J Rehab Med 15:133-140