SUSPENSION THERAPY
IN REHABILITATION
Suspension Therapy in Rehabilitation

MARGARET HOLLIS
M.C.S.P
Principal, School of Physiotherapy
Bradford Royal Infirmary

and

MARGARET H S ROPER
M.C.S.P
Lecturer in Physiotherapy
University of Cape Town

with a foreword by
SIR ARTHUR PORRITT
Surgeon Surgeon to H.M. the Queen
Surgeon to St. Mary's Hospital, Paddington
and the Royal Masonic Hospital, London

LONDON
BAILLIÈRE TINDALL AND COX
7 and 8 Henrietta Street, W.C.2
1958
Olive Frances Guthrie Smith
M.B.E. F.G.S.P (Hon)
1883 - 1936
To the memory of

Mrs G S
First published April 1950.

This book may not be reproduced by any means, in whole or in part, without permission. Application for reproduction should be addressed to the publishers.

© Bailliére, Tindall and Cox Ltd, 1950.

Made and printed in Great Britain by William Clowes and Sons, Limited, London and Reading for Baillière, Tindall and Cox Ltd.
FOREWORD

It is now more than a quarter of a century since Mrs Olive Guthrie Smith and I published an article in the medical press on Suspension methods in rehabilitation. The writing was mine the idea and the work were Mrs Guthrie Smith's. A friendship born amongst the slings and pulleys of her original suspension frame, opened through the years as I became more and more aware of her inventive genius, her originality and her drive, and more and more appreciative of her sparkling personality, her mercurial temperament and above all her humanity. I therefore deem it a great privilege to be able to write these few words in a book dedicated to her memory.

Her two disciples Miss Roper and Miss Hollis, have produced a veritable magnum opus, as a single glimpse at the list of chapters will show. That the original simple method now embraces such a very wide field of activities, that its use is world wide and that its application has increased steadily with the passing years—all go to show the intrinsic merit of the initial conception. To my mind, the keynote of the book is the stress laid by the authors on the importance of the individual patient. How suspension methods can now be applied to the different parts of and to the different ailments afflicting this individual patient is most lucidly and comprehensively set out in the book.

It will have a very wide appeal to a large field of professional workers, and it sets a seal on the great work of a great pioneer.

Arthur Porritt

London 1958
PREFACE

This book continues the invaluable pioneer work of Olive Frances Guthrie Smith who unfortunately died as it was being planned and demonstrates how sound the techniques which she developed, advocated and taught remain today in the light of further knowledge and experience.

The purpose of the book, as its title suggests is to provide an up-to-date practical textbook for all who use suspension therapy. The first part, containing Chapters 1 to 12, deals in detail with mechanical principles, techniques and methods of suspension, spring and pulley therapy and (largely written from Mrs. Guthrie Smith's own notes) the history of the development of these techniques.

The second part, from Chapter 13 onwards describes the clinical application of suspension, spring and pulley therapy to special conditions. These chapters have been contributed by different authors and we owe special thanks to the distinguished men and women who have, by their contributions, enabled us to present the use of suspension in a way which would otherwise not have been possible. Their names and the subjects on which they have written are included in the Table of Contents.

Sir Arthur Porritt, K.C.M.G., K.C.V.O. C.B.E. M.A. M.Ch., F.R.C.S. has been so closely associated with the development of suspension therapy and with the first publication of these methods that we were much encouraged after Mrs. Guthrie Smith's death when he agreed to write the Foreword.

Our thanks are also due to Dr A. E. Chester, Ph.D. M.Sc., of the Bradford Regional Radium Institute, who was kind enough to advise on and correct the physics in the book.

We are grateful to the following for the loan of photographs or blocks: Stanley Cox, Ltd. St. Benedict's Hospital. Hammersmith Hospital, the Editor of Physiotherapy and the Editor of The Swedish Institute Magazine.
## CONTENTS

### PART I

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Introduction</td>
<td>3</td>
</tr>
<tr>
<td>2  Historical</td>
<td>9</td>
</tr>
<tr>
<td>3  Explanation of the Apparatus</td>
<td>15</td>
</tr>
<tr>
<td>4  Suspension and its Relation to the Laws of Mechanics</td>
<td>28</td>
</tr>
<tr>
<td>5  Pulleys and Springs and their Relation to the Laws of Mechanics</td>
<td>41</td>
</tr>
<tr>
<td>6  The Technique of Suspension</td>
<td>50</td>
</tr>
<tr>
<td>7  The Application of Springs and Pulleys to Movement</td>
<td>65</td>
</tr>
<tr>
<td>8  The Application of Suspension for Movement in the Upper Limb</td>
<td>78</td>
</tr>
<tr>
<td>9  The Application of Suspension for Movement in the Lower Limb</td>
<td>86</td>
</tr>
<tr>
<td>10 The Application of Suspension for Movement in the Head and Trunk</td>
<td>95</td>
</tr>
<tr>
<td>11 The Application of Suspension for Support</td>
<td>104</td>
</tr>
<tr>
<td>12 The Application of Springs and Pulleys for Rested Movement</td>
<td>112</td>
</tr>
</tbody>
</table>
To our young artist, Miss Patricia Storey, of Skipton, we owe much, she has interpreted our ideas in the clear drawings which illustrate the text. Miss Storey herself owes much to suspension, for she is a quadriplegic polio who at the age of fifteen had to learn to use a weak left arm for all her activities. We were happy to aid her rehabilitation by giving her her first commission as a commercial artist. Mrs. Eileen Grice has patiently typed and re-typed the manuscript, and many colleagues have given help and advice and have devoted much time to checking the text. The Publishers have always been ready to help and advise us, and finally we should like to thank Miss Isabel Smith, M.C.S.P., without whose practical help and encouragement we could not have undertaken this task.

Margaret Hollis
Margaret H S Roper

Bradford and Cape Town
March 1958
PART 1
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Orthopaedic Conditions</td>
<td>127</td>
</tr>
<tr>
<td></td>
<td>by Miss J. A. Huggan, M.C.S.P., O.N.C.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Suspension Exercises in the Treatment of Cases coming under the Heading of the Rheumatic Diseases</td>
<td>141</td>
</tr>
<tr>
<td></td>
<td>by W. Yeoman, M.D., and Miss B. Savage, M.Sc., M.C.S.P.</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Physiotherapy in Spinal Paraplegia</td>
<td>147</td>
</tr>
<tr>
<td></td>
<td>by L. Guttmann, O.B.E., O.St.J., M.D., M.R.C.P., and Miss D.T. Bell, M.C.S.P.</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Rehabilitation after Amputation</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>by G.S. Thompson, M.Ch</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Suspension Therapy and the Geriatric Patient</td>
<td>194</td>
</tr>
<tr>
<td></td>
<td>by Miss P. Savin, M.C.S.P.</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Suspension Therapy for some Disorders of the Nervous System</td>
<td>208</td>
</tr>
<tr>
<td></td>
<td>by Miss M. Hollis, M.C.S.P., and Miss M. H. S. Roper, M.C.S.P.</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER I

Introduction

It has been stated that Celsius advocated swinging in a hammock for anxiety states. If this is the case, suspension therapy may be said to have its origin in ancient medical lore and may rank with other forms of physical therapy as amongst the oldest therapeutic agents used by man.

Physiotherapy frequently subscribes a major contribution to the total rehabilitation scheme and within the physiotherapeutic programme suspension, spring and weight and pulley therapy will often make provision for a valuable phase. A contribution to be of value must fit into the general pattern. What has gone before and what will follow after must be recognized and as far as possible understood by both patient and therapist. It is not claimed that the procedures described in this book are the only forms of self activity desirable in a certain phase of rehabilitation or indeed the only means of obtaining self activity. The part played by suspension in the total programme may be small and in some instance this form of self activity may not be required at all, and again the use of spring and weight and pulley circuits may have a limited sphere of application. However in many instances if these means are chosen and used with discretion a valuable link in the rehabilitation chain will be provided.

The use of discretion implies the 'weighing up' of a situation, the analysis of what has caused it and the choice and application of a procedure that will achieve a specific result. For the purpose of this text the situation under consideration will be the patient as a person and the disability from which he is suffering. The weighing up must take into account the impact on the patient of the disability and how he is facing up to the consequences. The analysis will include an assessment of the actual disability and must carry
that fatigue diminishes effective action. By the intelligent use of suspension, spring and weight and pulley circuits more repetitions with less general fatigue can be obtained.

**General Fatigue.** Fatigue may be a psychological reaction due to many factors that are outside the sphere of this book. Boredom has already been mentioned in this context and boredom will readily lead to fatigue. The skilful and imaginative use of suspension by preventing boredom can do much to delay the onset of fatigue.

It is well known that a muscle which is contracting isometrically will show signs of fatigue before a muscle which is doing the same amount of work by contracting isotonically. Apprehension and fear of 'hurt or harm' will engender general tension and unwanted isometric (static) muscle action, but the comfortable support of the suspension unit will give a sense of security and confidence which will do much to diminish such tension. Again the performance of a difficult movement provokes tension and excessive static fixator action, but the mechanical factors that operate on a moving part in suspension will decrease the amount of fixator work necessary for the co-ordinated performance of the movement. Hence, by giving confidence and a sense of security and by providing mechanical assistance to movement, the use of suspension can minimize isometric muscle action and delay the onset of fatigue. Therefore the muscle or muscles to be re-educated can contract more frequently before general fatigue sets in to hamper their efficiency.

**Local Fatigue.** According to many authorities on muscle development, if maximum strength of muscle is to be achieved, the muscles concerned must be worked to the point of fatigue. Accurate grading and localization of muscle action is readily effected by the use of suspension because in suspension the muscles that require special attention can be picked out and made to work locally. Further grading of effort for specific muscles can be supplied by using springs or weight and pulley circuits in conjunction with suspension.

Whilst realizing the importance of the group action of muscles and the importance of movement patterns that will
with its knowledge of the physiological and anatomical disturbances inherent in the disability. The choice and application of procedures to achieve a specific effect must be influenced by knowledge of the mechanical factors that operate both on the patient’s movements and on the apparatus being used. Finally, the specific result to be aimed at must go beyond what can be achieved by a particular activity, however important that may be. It must be extended to include the ultimate functional activity desirable for that patient for his occupation.

**Psychological Considerations**

The use of the apparatus described will, in many instances, provide an alternative and a different form of activity which will help to prevent the boredom that may well result from tedious repetitions of the same movements.

Again, when patients are severely handicapped, any means that will help them to move more easily or, as is often the case, that will enable them by their own volition to move at all, will be of value. The joy dawning in the faces of victims of poliomyelitis when they experience in suspension their first volitional movements is only one illustration of this important point.

Increases in the distance moved in the number of oscillations maintained or in the number of pounds lifted can be measured and recorded and so provide tangible proof of progress and valuable encouragement for further effort.

Finally, whatever the physical or mental state, probably the most important single factor of all is that the use of this apparatus automatically includes the co-operation of the patient.

**Physiological and Anatomical Considerations**

The physiology of the locomotor system is complex, and concepts and theories relating to its nervous control are still debated. However, at the present time there seems to be general agreement amongst authorities on the neuromuscular mechanism that repetition facilitates co-ordinated control of movement but
Added to neuromuscular dysfunction excess body weight often presents a further hindrance to movement, and in these cases suspension is again of great value in that the weight is taken by the flexible support and the physiotherapist is free to guide and assist movement.

**Mechanical Considerations**

Gravity weight, leverage, friction and momentum exert powerful influences on bodily movements. To quote a few examples:

A muscle that can lift a limb against gravity will not be working to full capacity if the limb in question is suspended.

The application of the same resistance to different points of a suspended limb will alter the weight arm and therefore the effort required to move the limb.

Uneven surfaces between rope and pulley will increase friction with the result that greater force will be required to move the rope than if the surfaces were smooth.

Speed of movement can cause a limb to acquire momentum to the extent of distorting the movement and altering the muscle work.

It will therefore be obvious that indiscriminate and careless technique can render treatment useless and even harmful and that an understanding of the mechanical principles involved is essential for effective use of the apparatus.

Water and suspension have much in common as media for physical treatment but a detailed discussion on their comparative properties is outside the scope of this work. However, a study of the fundamental mechanical principles involved will show that localized movement is more readily obtained in suspension than in water and if for some reason water is not suitable or is not available, suspension will provide a valuable alternative for more general movement.

**Personal Considerations The Physiotherapist**

In the practice of physiotherapy apparatus is only an agent to be used with an ultimate aim—the rehabilitation of the
bring all the muscles concerned into play, we consider that localization of work is an essential part in the re-education of weak muscles. We do not overlook the many instances when by using group action a muscle will come into play as part of the group, when an attempt to contract that muscle alone would achieve no response. However, we consider that, provided the muscle concerned can be induced to work in a 'localized manner', the accurate grading of effort to the point of fatigue for that specific muscle is a valuable part of re-education. It will be found that much of the apparatus described in the following chapters can be used to achieve such fatigue in specific muscles and that general fatigue and fatigue of fixators can be minimized by its use.

Loss of Elasticity in Tissues

If a movement is limited by loss of elasticity and contracture of tissues, the mechanical and physiological factors that are provided for by the use of suspension and reciprocal pulley circuits for the localization of muscle work will also operate. All the available muscle power can then be directed towards 'elaborating' the shortened structures, and frequently a greater range with less pain can be obtained by these means than by other procedures. The fact that unwanted muscle work is lessened and more readily eliminated is a possible explanation of this phenomenon. Another helpful factor is that in suspension the judicious use of momentum will often enable the patient to take the limb 'that much further' and so achieve the desired increase in range of movement.

Relaxation

Suspension is also a valuable asset to the practice of relaxation, and the flexible support it provides will often enable more movement to occur with less antagonistic and unwanted muscle work than is possible without its aid. Therefore it is often found that self-activity so vital from the psychological as well as the physiological viewpoint, is often possible in suspension to an extent that would not be possible without this form of support.
CHAPTER 2

Historical

The techniques used in physical rehabilitation that are described in the following chapters grew from pioneer work begun in these islands between 1914 and 1918. It was during the First World War that Dr. J. B. McConnell designed his weight and pulley apparatus and Mrs. Guthrie Smith first used a reciprocal pulley circuit. Dr. McConnell's apparatus was widely used for many years and just before and during the first part of the Second World War Mr. J. H. Colson developed and amplified the techniques and applications of weight and pulley therapy.

Suspension and spring therapy evolved from Mrs. Guthrie Smith's original experiment with a reciprocal pulley circuit, and, as the major part of this book is devoted to her work, a brief history of its development may be of interest.

The development of these techniques may be traced through four main periods:

Period I 1914-1918

In the First World War the wounded soldiers were sent to Command Depots as soon as they were able to leave hospital as walking cases. Some of these men were very severely incapacitated with grossly septic wounds and progressively stiffening joints. Thousands of soldiers were accommodated in the huddled Command Depots and one of these huts was the Massage Department with a medical officer in charge and a staff of approximately forty qualified members of the Incorporated Society of Trained Masseuses. The usual treatments at that time were Massage, Swedish Remedial Exercises, Galvanism, Faradism and Radiant Heat. Mrs.
patient—therefore the physiotherapist must direct, but must not rely on "the agent" to do all the work. In order to direct an agent it is necessary to understand its potentialities and its limitations. As we have attempted to show the potentialities of this apparatus are many and varied, but, since it is used in the treatment of the even more numerous and varied physical disabilities of infinitely variable human nature, obviously its use will be subject to limitations. A lively appreciation of human reactions and an ability to adapt personal approach and therapeutic procedures to suit such reactions are essential qualities that must never be neglected by any physiotherapist. This apparatus will only be an effective agent when it is directed by a physiotherapist who is exercising these qualities of understanding and adaptability.

This book does not claim to be a complete survey of every treatment that can be given by using suspension, springs or pulleys. An attempt has been made to enumerate the essential principles governing their use and to explain the basic techniques necessary for the implementation of these principles. It is hoped that the examples chosen will help to clarify the principles and as need and occasion arise, will enable the reader to adapt and amplify the fundamental techniques described.
had the usual busy out patients department but practically no ward cases in those days. Then suddenly some adult polio cases were admitted under the care of Dr Wilfred Harris, such cases were very rare at that time. Massage and passive movements were ordered and Mrs. Guthrie Smith asked for a single balkan beam to be fitted over a patient’s bed in a medical ward, a most unusual request. This was granted and reciprocal pulleys were tried out on the patient’s arms. One arm showed a little power and, after a period of bilateral work, power improved in both arms. However a much more important development occurred as quite by chance, Mrs. Guthrie Smith slipped both ends of the rope round the lower limb to support it for a few moments thereby causing it to be free of bed clothes also the ropes had counterbalanced gravity and for the first time a tiny movement of the leg was noticed. A new method of movement had been discovered for physiotherapy—Weightless—and horizontal in direction.

At that time Mr. A. E. Portrett, M.Ch. F.R.C.S. (now Sir Arthur Portrett, K.C.M.G., K.C.V.O.), became interested in this new idea and published an article with Mrs. Guthrie Smith in the British Medical Journal in 1931. In the meantime, following a lecture-demonstration to a group of old students at King’s College Hospital the staff at that hospital began to practise and teach suspension therapy.

In the year 1936 the authorities of St. Mary’s Hospital decided to start a Fracture Clinic so that all fractures and recent injuries were under the care of one surgeon. The late V. H. Ellis, F.R.C.S., was appointed to the new department, and one of the authors, who was a senior assistant at that time, was selected to assist in the clinic. The co-operation between surgeon and physiotherapist produced most satisfactory results in this field and many new methods of suspension therapy were evolved. An overhead bar was put up in the department so that limbs could be easily suspended and patients’ activity supervised. Experiment with suspension therapy for spinal conditions followed.

It was not long before the new knowledge was put to good use, as one of the young students was struck down with a complete sensory and motor paralysis. This girl was cared
Guthrie Smith was transferred from a Base Hospital to one of these camps as Head of the Massage Department.

It was not long before she found that the results obtained with stiff joints in particular were disappointing so she thought a rope and pulley might help and with the medical officer's approval this device was fixed to the wall behind and above a selected patient—a very powerful unco-operative guardsman who had been ordered stretching exercises for the muscles of the back of his leg. This man very much resented being hurt, but apparently with this simple pulley and rope he was quite pleased to hurt himself! When told what to do he pulled most willingly upon the free rope end, the other end being fixed to his foot by twisting it round his army boot. Having found that this was a successful and co-operative method of treatment, it was not long before the system was worked out for all joints, with the best gymnastic starting position as a basis. This is now known as Reciprocal Pulley Treatment.

At that time Mrs. Guthrie Smith was invited by the Incorporated Society of Trained Masseuses to give a Lecture Demonstration at the Annual Congress. It was stressed that no hooks or bolts or any such things could be fixed to walls, ceilings or floors. Therefore a portable structure had to be thought out, to which could be fixed all the pulleys and other gadgets. So the first apparatus was made. It had the appearance of a wooden goal post with feet to balance it, and in this one framework it was possible to demonstrate pulley and weight exercises for the arm, reciprocal pulleys for shoulder and hip also an apparatus known as the boot to stretch the posterior calf muscles and to obtain dorsiflexion of the ankle joint (Plate I). Two soldiers were allotted to assist with transport and to act as patients.

Period II 1919–1939

After the First World War Mrs. Guthrie Smith joined the staff at the Swedish Institute under Dr. Justina Wilson, who was also the Medical Officer in charge of the Electrical and Massage Departments of St. Mary's Hospital, London. They
The photograph of this patient was taken years ago and shows a first and crude attempt to relax and extend spastic limbs. The chief interest lies in the fact that at that time, ten or more years ago we were not aware of how to make use of reciprocal inhibition, or at least that it had a very practical application to our work in physiotherapy for the purposes of relaxation. It will be noted

1. That the limb was held in extension, which though a useful technique for this case was not the best way of obtaining extension.

2. That all the finer points of the technique of suspension are missing—the limbs are not properly supported in the ways now advocated.
SUSPENSION THERAPY

for at St. Mary's Hospital, and survived, but it was difficult to know how much recovery would take place.

It was probably due to the efforts to assist this girl that the "Standard Apparatus" was designed. After consultation with the medical officer in charge of the case, Mrs. Guthrie Smith submitted a sketch plan of an apparatus she thought would be helpful. This had to be portable, so that it could be removed at night, it also had to be stable so that it would give total support and not cause any uneven pressure. The buoyant suspension prevented uneven pressure on the patient and as an extra precaution sorbo pads were placed inside the canvas slings. Thanks to weightless movement it was soon possible to demonstrate that power was returning.

Period III. 1939-1945

In the Second World War, soldiers and civilians were sent in due course to the Emergency Medical Service Hospitals in various parts of the country, so it became necessary to divide the staff and students of the Swedish Institute; some remained in London at St. Mary's and the remainder were evacuated to Buckinghamshire, to work in St. Mary's Sector Hospitals. The authors were concerned in the work in the hospitals both in the Sector and in London and were therefore able to help with the advancement of suspension therapy.

At the same time this work was also being used extensively in the Sector administered by King's College Hospital.

During these early days of the war spring therapy came into being. Work against spring resistance had been recognized as a method of building up muscle power for some years but, so far, springs had not been used for the purpose of re-education. During the early 1940's, quite by chance, Mrs. Guthrie Smith acquired some springs and with her usual acumen and originality she soon realized the possibilities inherent in this form of self-activity. A large number of Terry's springs were bought and sent to the country, and they proved a most valuable addition to suspension exercises which could then be graded to suit the weakest patient or to give strong resistance to the convalescent (Plate II).
Being a "new" treatment, suspension therapy caused considerable interest in surrounding hospitals, and Mrs. Guthrie Smith was asked to give lecture-demonstrations at St. Bartholomew’s Sector Hospital at Hill End and Stoke Mandeville (now the famous "Paraplegia" hospital). The American physiotherapists working with the U.S. Army under Lieut. Kathryn Bier also came to St. Mary’s Hospital for a demonstration of this work. It was through Miss Bier that a very interesting contact was made with America, and she introduced these methods to several localities in the United States.

During the polio' epidemic in Malta in 1943 suspension therapy was used extensively by the team of chartered physiotherapists who went out under the direction of Professor Seddon. The frames, slings and springs were all made by the armed forces stationed there and by residents on the island. It was found that, by having wooden frames fitted to every bed, the patients had adequate treatment, which would have been impossible for the limited number of physiotherapists to give without this type of apparatus.

Great interest was aroused when a demonstration was given to the late Lord Horder, Brigadier Wand-Tetley, the late Sir Robert Stanton Woods and Mr. Henry, F.R.C.S., by Mrs. Guthrie Smith and her staff at the Swedish Institute.

In consultation with makers of medical equipment the Guthrie Smith suspension frame had been gradually evolved, and in 1942 the apparatus for suspension and spring therapy was included in the list of equipment issued by the Ministry of Health for use in Physiotherapy Departments.

In 1946 suspension and spring therapy were included in the syllabus for the training of students for the examinations of the Chartered Society of Physiotherapy, and the equipment was used for the first time in the Society’s practical examinations in 1947.

**Period IV. 1945–1958**

With the return of peace which allowed for a free exchange of ideas this work became known in many parts of the world. In
An early attempt to use springs as resistance.
CHAPTER 3

Explanation of the Apparatus

In order to perform a movement in suspension it is necessary to have a rigid overhead point and a flexible, adjustable suspensory unit which consists of a rope and sling (Fig. 1). While
1949 Mrs. Guthrie Smith herself purchased and sent to Greece a complete unit for suspension and spring therapy. In 1952 the second edition of *Rehabilitation, Re-education and Remedial Exercises* was translated into Jugoslav at Zagreb.

Now, in 1958, a year after the death of the pioneer in this work, although changes in thought and practice have modified the techniques, suspension, springs and pulleys will be found wherever physiotherapy is “active”. 
stability is given by using circular discs of large diameter for the feet, thus also avoiding damage to the floor.

The frame is made of light gauge steel tubing of \( \frac{1}{2} \) in. diameter, to be strong enough to take the weight of the heaviest patient. In order to offer fixed points, the long top and bottom rails, the overhead cross-bars and the end cross-bars are notched at intervals of 1 or 2 in. to provide positive fixation and adequate anchorage. The uprights are also provided with hooks for the various attachments needed in some of the exercises.

The frame must be of suitable size in relation to the bed or treatment couch introduced within it. The height is selected in accordance with experience, but it will be found that a clearance of about 5 ft. will avoid jamming of the suspension ropes or their mutual interference. A greater height allows too much swing and all fine work will be lost.

Other methods of overhead fixation can be achieved by:

- Strong wire mesh supported on uprights of wood or metal and arranged in the form of a frame over a single bed, or where many patients are to be treated simultaneously the wire mesh covers an extensive area over several treatment couches and is then hung from the ceiling or fixed to the walls, so that there are no uprights which may impede movement or access.

- Balkan beams, with an additional number of cross-bars. The roof unit is usually serrated in order to give the required grip to the ropes which might otherwise slide.

- Bamboo has been used in countries such as Burma and has the advantage that it is already serrated.

Plate V illustrates a portable tripod which was designed by Miss M. B. Rose, M.C.S.P.* and is suitable for use in the home for an individual patient. The top piece is an inverted, three-sided pyramid with flattened corners; into the apex a strong hook is screwed. To each side of the pyramid the suitably bevelled end of a leg is fastened by a strong hinge, so that the legs will fold flat together, or open to the desired distance controlled by a cord on cup-hooks on the inner surfaces approximately half-way down the legs. From the top large hook

* Thanks are due to Miss M. B. Rose, M.C.S.P., and the Editor of Physiotherapy for permission to publish this section and diagrams.
it is possible with only one fixed point and very few suspensory units to achieve much activity on the part of the patient, limitations will eventually be felt by the lack of adequate equipment. It is therefore usually necessary to employ some form of frame offering more than one fixed point. Variations on the simple rope and sling are also required in order to give maximum power to the physiotherapist in raising the patient into suspension and to give support with maximum comfort.

The Suspension Apparatus

All apparatus should be so constructed that it is as strong and serviceable as possible; it will then last for years even with the wear and tear of a busy out-patients' department.

Types of Frame

The illustrations in Plates III and IV show very clearly the different types of apparatus which are specially constructed and are suitable variously for use in the department, wards or in private practice. These specially constructed frames all conform to the mechanical principles of

1. Stability for the largest movements and the heaviest patients.

2. Fixation by a multiplicity of points.

3. Clearance between fixed points and patient.

The special frame made for suspension is somewhat pyramidal to provide stability, and is made in five parts, viz.: (a) the top (roof unit); (b) the two side units; and (c) two loose bars which connect the latter near the feet. The connections consist of tapered bolts and nuts which are easily fixed.

The standard dimensions are:

- Height: 7 ft. 0 in.
- Length: 8 ft. 0 in.
- Width at base: 3 ft. 6 in.
- Width at top: 2 ft. 0 in.

The dimensions given are recommended where the apparatus is to be used for strenuous exercise. Additional
and the suspension ropes are hung in place by means of window poles (Plate VI (a)).

Lateral bars can be fitted over the suspension bars in any position and are made of wood 2 in. x 2 in. These bars are 10 ft. long and due to their obliquity allow for a range of 3 ft. of horizontal movement at the normal height of the plinth. The tip of the lateral bar is specially shaped to grip the suspension bar to prevent the patient's movements causing an upward riding (Plate VI (b)).

A hook with a wing-nut, which acts as the resistance point, is fitted through a hole, a number of which are spaced at 6-in. intervals so that the height of the lateral resistance can be correctly adjusted. Spring resistance or weight and pulley resistance is applied, and in the latter case the rest position is obtained by allowing the weights to come down to the floor. The direction of the applied resistance is carefully adjusted so that it is tangential to the midpoint of the arc of movement (see Chapter 7).

By this means unilateral or bilateral graded resistance can be applied to most movements of the trunk and limbs.

**Ropes**

The ropes are of stout cotton and are of two types:

**The Single Rope.** One end of the single rope is finished with a ring for attachment to the frame or fixed point. The rope then passes through one end of a wooden cleat, through a steel spring-clip for attachment to the slings and back through the other end of the wooden cleat, and is finished with a knot. This knot is the only one which should be made permanently in the rope (see Fig. 9a).

**The Double Rope.** This is used for supporting the heavier parts of the body such as the pelvis and thorax, but this type of rope will also be found useful for supporting patients with very heavy lower limbs. In this case a rope strop is fixed to the casing of an upper pulley and the rope continues through one end of the cleat, through the casing of the second pulley from which is hung a steel spring-clip, and
two canvas slings with loose covers of parachute silk are suspended by fish line.

For use in a very small department the following adaptation designed by Miss D. B. Parsons, M.C.S.P., is of great value. Two metal bars with pegs spaced at 2-in. intervals are fixed to the walls of the department separated by a distance of 2 ft. On to the pegs is fitted a notched bar which has at one end a hole to fit a peg on one bar and at the other end a notch to fit the corresponding peg on the opposite bar. With several of these notched bars each part of the body can be treated and the apparatus does not involve the use of floor space (Fig. 2).

**Fig. 2. Overhead fixation for a very small department.**

1. (A) The long bars fixed to the walls.
2. (B-B) The movable serrated, notched cross-bar.

**Apparatus to Provide Fixation for Resistance in a Horizontal Direction**

*(CONTRIBUTED BY MISS D. F. TALBOT, M.C.S.P.)*

This apparatus has been devised to work with the ceiling suspension used at the Robert Jones and Agnes Hunt Orthopaedic Hospital. The suspension bars are 8 ft. from the ground
then the rope continues through the other end of the cleat, over the upper pulley and then down to the central hole in the cleat where the permanent knot is tied (Fig. 3A). The single rope is shortened and the part to be suspended is raised by lifting the cleat, the operator having to apply sufficient force (muscle effort) with the “anti-gravity” muscles to raise the weight of the part. The double rope is shortened by the application of a downward pressure on the cleat, the rope sliding smoothly over the double-pulley circuit. The mechanics of this double-pulley circuit are discussed in Chapter 5, but it is obvious that, in addition to the mechanical advantage obtained by using a double-pulley circuit, the action of raising the part is made easier because the operator works entirely with the powerful “with-gravity” muscles, the operator’s movement being in the direction of the pull of gravity.

**Slings**

The belts or slings are usually made of strong canvas, bound and shaped and finished with rings for easy attachment to the clips on the ropes. The narrow sling or single sling is used to support the limbs, the two ends being brought together for suspension by a single rope (Fig. 3b). The wide or double sling is used to support the pelvis and thorax, and extra rings are attached to the side of these slings for shoulder and perineal straps to keep them in place when energetic work is performed (Fig. 4). The head sling is a specially shaped sling

![Fig. 4. Body sling.](image-url)
(A) Double rope.  (C) Three-ring sling ready for use.
(B) Single rope.  (D) Three-ring sling.
(E) Single sling.
then the rope continues through the other end of the cleat, over the upper pulley and then down to the central hole in the cleat where the permanent knot is tied (Fig. 3A). The single rope is shortened and the part to be suspended is raised by lifting the cleat, the operator having to apply sufficient force (muscle effort) with the “anti-gravity” muscles to raise the weight of the part. The double rope is shortened by the application of a downward pressure on the cleat, the rope sliding smoothly over the double-pulley circuit. The mechanics of this double-pulley circuit are discussed in Chapter 5, but it is obvious that, in addition to the mechanical advantage obtained by using a double-pulley circuit, the action of raising the part is made easier because the operator works entirely with the powerful “with-gravity” muscles, the operator’s movement being in the direction of the pull of gravity.

**Slings**

The belts or slings are usually made of strong canvas, bound and shaped and finished with rings for easy attachment to

![Fig. 4. Body sling.](image)

the clips on the ropes. The narrow sling or single sling is used to support the limbs, the two ends being brought together for suspension by a single rope (Fig. 30). The wide or double sling is used to support the pelvis and thorax, and extra rings are attached to the side of these slings for shoulder and perineal straps to keep them in place when energetic work is performed (Fig. 4). The head sling is a specially shaped sling...
Fig. 5a. (A) Pulley and clip (used at the lower end of the double rope). (B) Rope compensating device. (C) Metal compensating device.

Fig. 5b. A simple overhead pulley fixation which is hung on to the wall bars.
rather in the form of a cap and should always be used with a single rope attached to either end. The three-ring sling is a narrow belt made either of stitched canvas or of webbing. It has a central ring for attachment to a single rope and a ring stitched to each end through which the belt itself is slotted to make two loops. This sling is used for supporting the hand and wrist or the foot and ankle. (Figs. 30 and 31.)

Pulleys

A pulley consists of a small grooved wheel fastened by a pin or axis into a block. The wheel may move on the pin or may move over ball bearings which in turn move on the axial pin. The former type is more commonly used as it is much cheaper.

The pulley may also vary in the fixation of the block or casing. Some pulleys are fixed to a type of bracket which can be screwed into a wall or ceiling laterally or vertically. These pulleys have only one direction of movement and care must be taken that the rope does not chafe in use. Most standard types of pulley have a compensating device in the block which allows movement in a second plane; this type is less liable to chafe the rope as the pulley block adjusts to the pull. The common types of compensating device are (a) A rope strop passing from the pulley block which can be tied to a beam or bracket. (b) A swivelling device consisting of either a pin and cuff or a universal joint (Figs. 5a, b and 5a, c). Use is made of the rope strop at the upper attachment of the double rope and double-pulley circuit described under Ropes.

Springs

There are two types of springs:

Short tension springs (Fig. 6a). The type of suspensory unit hitherto described restricts movement to its simplest form, i.e. in a single and usually horizontal plane and about a single axis. If a short tension spring is introduced into the suspensory unit, additional movement will occur in a vertical plane. The amount of vertical movement will be relative to the type of spring and the properties peculiar to springs. The
Fig. 6

(A) Short tension springs.
(B) Short spring unit.
(C) Long spring unit.
(D) Spreader for use when springs are placed in parallel.
(E) Handle—note the number of hooks for attachment of more than one spring or rope.
(A) The universal suspension frame.

(B) The ward model suspension frame.
(A) The transportable suspension frame.

(B) The bed frame. The feet are fixed under the legs of a bed.
(A) A portable tripod frame suitable for use in private practice.

(B) Detail of the tip of the bar.
(A) Suspension combined with resistance applied in a horizontal plane.

(B) Detail of the tip of the lateral bar.
Springs employed for the purposes explained below are usually of short initial length (about 4 in. long), so as to provide for a small range of movement, and are of various tensions according to the functions they have to perform. When using the short tension springs for suspension they are selected by their tension to support the weight of the various parts of the body.

For hands and feet . . . Light tension springs
For head, thigh and upper Medium tension springs
arm
For thorax and pelvis . . . Strong tension springs

When short tension springs are included in the suspension outfit the entire body can be accommodated in comfort and a sense of buoyancy prevails. Pressure is relieved from all soft parts of the body and the general sense imparted to the patient is that of floating on air or in a buoyant medium. All movements of the body in the horizontal plane are entirely unimpeded while the spring suspension admits also of small vertical movements. General rhythmic movements, when undertaken with a minimal or maximal effort, afford a sense of exhilaration, which in many cases is itself of no little therapeutic value; and it is difficult to describe if not experienced.

Shock-absorbers. This type of spring may also be used as a shock-absorber. In this capacity they are used when treating paralysis with sensory loss and trophic changes, because their use causes variation in pressure at the points of contact of each sling.

Resistance. The short tension springs are also used for resisting movements involving a very short range, such as exercise of the neck muscles. These springs must on no account be strained and they are not suitable for large range resistance work.

Co-ordination. Spring suspension of the body is useful when it is desirable for a patient to undertake simple or complex co-ordinated movements, as it is then possible to make use of the ability to produce movement in two planes within a limited range.

Relaxation. Suspension with the addition of springs with the patient in the supine position is found greatly to assist in in-
dancing relaxation. The patient is more comfortably supported than in simple suspension. To summarize; short tension springs are used as follows:

1. To increase comfort and act as shock absorbers.
2. To give buoyancy to movement and to encourage rhythm in movement.
3. As resistance for short ranges of movement only.
4. To permit co-ordinated movements in more than one plane.
5. To assist relaxation.

Long Spiral Springs. These springs are often referred to as helical springs (from the Greek helix—a spiral). They are considerably longer than the type already described, having an average length of 10 in. The spring metal is fairly soft and the springs yield easily.

Each spring is fitted at either end with a split clip which is also capable of rotating in the tapered end of the spring to allow rotatory adjustment without distortion. The poundage of each spring is stated on metal tabs affixed to the split clips.

Poundage is the method of calibration used for these springs, and the poundages quoted for the “standard” springs are the pressures exerted when the springs are fully extended. “Standard” springs are supplied in the following poundages: 5 lb.; 10 lb.; 15 lb.; 20 lb.; 25 lb.; 30 lb.; 35 lb.; 40 lb.; and 50 lb. It will be found in practice that with a set of springs consisting of two of each of the above poundages it is possible to undertake innumerable treatments for patients with every degree of muscle power.

Distortion, deformation or deflection. There is a limit to which a spring may be extended before permanent deformation occurs; this limit is defined as the range of the spring and is usually just short of the maximum poundage for that spring. The spring is at its limit of safe extension when the cord which is found passing through the spring is fully stretched. The coils of a spring normally lie in close and uniform proximity to one another and deformity is indicated when they fail to do so or are bent by deformation.
Helical springs may be used:

1. As resistances to movements of either large or small range, providing the point of deformity of the spring is not reached.

2. As assistances to movement, provided they are previously deflected by the weight of the part supported or by voluntary muscle action so that their recoil will assist movement.

3. As oscillators, since a spring will act alternately as an accumulator of energy and then expend that accumulated energy. The mechanics of these uses are described in Chapter 5 and the methods of rigging springs are shown in Fig 6.
CHAPTER 4

Suspension and its Relation to the Laws of Mechanics

Give me a place to stand on and I will move the world
ARCHIMEDES

To assist early self-activated movement in patients at all stages of their disability, it is necessary to try to understand the difficulties against which they have to contend. Since a complete understanding of the value and uses of suspension is necessary for its effective application, the relationship of suspension to the laws of mechanics must be fully understood.

Mechanical Opposition to Movement and its Solution

Any enfeebled patient who lies helpless in bed, from whatever cause—he it surgical interference, recent injury, paralysis, or painful joints—is hampered by physiological and mechanical factors when movement is required. His limbs are too heavy for his weakened muscles, and on analysis it is found that these impediments are of several types, all acting to obstruct movement. These forces are due to internal resistance, friction and weight, and by suspending the body advantage is gained over these three disadvantages.

Internal resistance. There are internal factors which may oppose movement. These are:

A general tensing of the body through fear, due to physical and mental conditions.

The natural subconscious protective contraction set up in opposing muscles, if pain is likely to occur on action of the prime movers.
Any undue action of the fixator muscles controlling the joint.

These forces, which we have termed internal resistance, can be controlled by relaxation, adequate support and, above all, by the patient’s active cooperation through self-activated movement. Such relaxation and support is a marked feature obtainable by the simple expedient of suspending the injured part.

**Friction.** Friction operates whenever one body tends to slide or slides upon another.

When the body is suspended a sliding movement occurs only at the points of contact of the rings and hooks as movement is performed. Both these surfaces are rounded and therefore the points of contact are very small (Fig. 7) and friction is virtually eliminated. The body is thus free to move more easily and the physiotherapist need not consider external friction as a resistance to movement when suspension is used.

**Gravity and weight.** The force of gravity is counteracted because the weight of the body is fully supported in the slings and the downward pull of the earth on the body is balanced by the upward force of the supports. They are said to be in equilibrium. This balancing of the force of gravity diminishes fixator and controlling muscle work on the part of the
patient and frees the operator from the task of supporting the body while movements are performed. The hands are freed for the more important tasks of controlling the movement, palpating the muscles and generally guiding the work performed by the patient. It is also possible to offer manual assistance or resistance as desired.

Levers. The primary desire in suspending the body is to facilitate movement, and to this end the laws of leverage must now be considered, as the movement of each part of the body may be regarded as movement of a lever. A lever consists of a rigid bar which moves about a point known as the fulcrum. The bones of the body represent the rigid bar and the joints act as the fulcra. Two forces act upon a lever, one known as the weight, which is represented by the part of the body to be moved, and the other known as the effort, which is represented by the action of the muscles. These two act at different points on the lever, and their relationship to each other and to the fulcrum determines the type or order of lever.

There are three orders of lever illustrated in Fig. 9, and it will be realized that the First order of lever is one of Balance, in which the moment of force on each side of the fulcrum is the same. The moment of force is the product of the force applied multiplied by the distance at which it is applied from the fulcrum and is expressed either as pound inch (lb. in.) or pound feet (lb. ft.). Thus, Fig. 8 may be expressed

Right-hand force \times distance = 2 \times 6 = 12 \text{ lb. in.}
Left-hand force \times distance = 4 \times 3 = 12 \text{ lb. in.}

![Fig. 8. Moment of force.](image)
Fig. 9. (A) A balance lever.—Foot tapping the ground.
(B) A power lever.—Heel raising from the ground.
(C) A speed lever.—Flexion of the forearm.
It will therefore be seen that balance can be achieved by varying the length of the weight arm and the effort arm in relation to the weight to be moved.

The Second order of lever is one of Power, because it is found that when the weight to be moved is nearer to the fulcrum than the effort, relatively less effort is required and a Mechanical Advantage will be gained. This type of lever results in a powerful movement which is often slow.

The Third order of lever is one of Speed, when the effort is applied near to the fulcrum and the weight is a greater distance away. A small movement of the nearer part of the lever results in a large movement of the more distant part, but the efforts required to perform this movement will be great. This is the commonest order of leverage in the human body.

In the body it is found that the length of the power arm cannot be altered as the power is applied at the attachments of the muscles, but effort for some muscles may be increased or decreased by altering the length or weight of the weight arm (Fig. 10). For example, the deltoid works more power-
fully when the arm is abducted with the elbow straight because the length of the weight arm is greater than when the elbow is bent. If a weight is held in the hand, then the effort required of the deltoid will be greater still.

If the same movement is performed with the arm in axial suspension, the movement is weightless since the arm is completely supported, in which case, provided movement is initiated by the operator, it will not make much difference whether the elbow is straight or bent.

This does not apply to other varieties of suspension because then the laws of motion operate,

\[\text{Motion}\]

\textit{Inertia. The mass of a body is its tendency to resist a change of state or motion.}

A stationary body will remain at rest indefinitely unless acted upon by a force.

A moving body will continue to move with the same velocity until acted upon by a force.

If adequate force is applied to a stationary body it will cause movement, and the degree of acceleration will be proportional to the force applied and to the direction in which the force is applied. When muscles are extremely weak they may be able to contract, but unable to overcome the inertia of the part on which they act. In this case the physiotherapist will need to initiate the movement and the weak muscle may then maintain it. In axial suspension the movement is easily initiated as the limb moves freely and the effort for the physiotherapist is thus reduced. The operator is also able to know whether the patient is continuing the movement or not by withdrawing assistance once the movement has started and then observing the speed and range of the movement. Once the movement has been initiated the patient may maintain it by the application of further force in the direction of the movement already occurring, or the movement may cease completely due to:
1. Inability of the patient to apply the necessary continuing force.
2. Contraction of the opposing muscle group.

**Velocity.** Alternatively, the movement may alter in velocity—that is its speed in this particular direction. It may move more slowly or faster—with decreased or increased velocity—in accordance with the abilities of the patient's muscles.

**Gravity.** If the body is not axially suspended but suspended in such a way that gravity plays a part in the movement, then gravity may assist the motion, when the suspended part will fall with constant acceleration. If gravity resists the motion, the suspended part will come to a halt on meeting a force equal to that which has been initially applied.

**Acceleration** of movement occurs when increased force is applied to a moving part or if a stationary part is made to move. This may be achieved by the patient applying muscle power to a movement initiated either by himself or by the operator, assisting the movement to gain a change in speed.

**Deceleration** of movement occurs as the initial force is expended or when an opposing or braking force is applied both gradually and insufficiently to bring the movement to an immediate "halt". Deceleration may indicate the onset of fatigue, and is also produced when the patient inhibits the movement by contraction of the antagonists or when the prime movers are not sufficiently strong to complete the movement.

**Oscillation.** An object will oscillate when opposing forces are applied alternately. Each force must be sufficient to overcome the inertia of the present movement and reverse it. The amplitude of the oscillation will depend on the force applied. Oscillating objects always expend energy in one-half of the movement and store it in the other half. This is discussed further in relation to the mechanics of springs.

**Natural rhythm.** All objects which are capable of producing movement do so with a natural rhythm. This is an individual feature which is inherent and related to the mass of the object concerned and the arc in which the movement will take place. Natural rhythm is the most economical speed for
movement from the point of view of the effort involved. When a movement occurs in suspension the natural rhythm may be more easily observed because so many resistances to movement have been eliminated or counteracted. When the natural rhythm has been estimated then the speed of the movement may be altered by command or assistance and a new rhythm set up.

*Momentum* represents the quantity of motion that a force can impart to a body in a given time and may be expressed as

\[ \text{Mass} \times \text{Velocity} = \text{Momentum}. \]

Once movement is initiated use is made of momentum to decrease the effort by increasing the speed of movement. The effort is increased when the speed of movement is decreased, as then momentum is of less assistance. In this way work may be graded and the effects of changing the rhythm of movement can be most easily estimated when suspension is used.

**Vertical or Pendular Fixation**

If each part of the body to be supported is suspended from a point above the centre of gravity of that part, then vertical fixation is used and movements performed with this method of suspension will be pendular.

*TWO EQUAL FORCES ACTING AT A COMMON POINT AND IN OPPOSITE DIRECTIONS WILL RESULT IN A STATE OF EQUILIBRIUM.* If each part of a limb is suspended separately at its centre of gravity, the limb will rest in equilibrium.

If an initiating force is then applied in one direction, the movement arising will be pendular, the amplitude of the swing depending on the force applied and the length of the rope.

A movement will first occur in an upward direction away from the force, and at the moment when the force equals the pull of gravity, providing the initial force has not been amplified, the limb will return to equilibrium and then will rise on the opposite side by reason of the momentum gained on the downward movement (Fig. 11). This alternating movement on each side of the resting position will continue as an oscillatory movement diminishing in amplitude until the
initial energy expended as force is consumed. The movement may be prolonged by the application of additional force in the direction of the movement, or it may be halted by the application of an opposing force in the opposite direction.

A moving pendulum swings because the weight of the bob (supported limb) moves its mass; its time of swing is proportional to the square root of the length of the pendulum. If the length of rope is too great, then the swing will be distorted.

Each complete swing of a pendulum occupies a constant interval of time, so long as the angle of swing is not more than 30° on either side of the vertical. This timed swing is used when re-educating rhythmical movement.

Fig. 11. (A) The swing of a pendulum. (B) Pendular movement in axial fixation.

Axial or Balanced Fixation

If all parts are suspended from a common point immediately above the axis of the joint to be moved, then the movement will no longer be pendular but will occur in a single horizontal plane, and gravity will not exert a pull at any part of the movement. The movement will still obey the laws of force, momentum, acceleration and oscillation but will require the addition of force other than gravity in order to maintain it.
In practice vertical fixation is used where support is required, because the limb remains in equilibrium in the starting position. Axial fixation is used for motion, because the range is not limited by the length of the rope, as in a pendular movement, and the amount of force required (muscle effort) is potentially equal at all parts of the movement subject to the physiological abilities of the patient (Fig. 12).

![Diagram of vertical and axial fixation]

**Fig. 12.** (A) A method of proving the horizontal plane of movement in axial fixation. (B) Axial fixation for the lower limb.

**Variations of Fixation from Axial—Eccentric Fixation**

There are four directions in which a fixation point can be altered:

1. Medial from midline.
2. Lateral from midline.
3. Proximally from the moving joint.
4. Distal or away from the moving joint (i.e. approaching vertical fixation) (Fig. 13).

**Medial or lateral.** If all ropes together are moved from axial fixation, the limb will move to a new position towards the point of fixation and will rest motionless in equilibrium; for
initial energy expended as force is consumed. The movement may be prolonged by the application of additional force in the direction of the movement, or it may be halted by the application of an opposing force in the opposite direction.

A moving pendulum swings because the weight of the bob (supported limb) moves its mass; its time of swing is proportional to the square root of the length of the pendulum. If the length of rope is too great, then the swing will be distorted.

Each complete swing of a pendulum occupies a constant interval of time, so long as the angle of swing is not more than 20° on either side of the vertical. This timed swing is used when re-educating rhythmical movement.

Fig. 11. (A) The swing of a pendulum.  
(B) Pendular movement in axial fixation.

Axial or Balanced Fixation

If all parts are suspended from a common point immediately above the axis of the joint to be moved, then the movement will no longer be pendular but will occur in a single horizontal plane, and gravity will not exert a pull at any part of the movement. The movement will still obey the laws of force, momentum, acceleration and oscillation but will require the addition of force other than gravity in order to maintain it.
example if the leg is suspended to obtain movement at the hip joint and the fixation point is moved in the direction of adduction and medially from axial fixation, then the leg will swing into adduction and remain in that position. When movement is performed with such fixation then the leg will rise as it is abducted and fall as it is adducted and movement will occur around half a pendulum (Fig. 14). In the example quoted the muscle work of abduction will be resisted and the movement of adduction will be assisted, but the muscle work of adduction is not necessarily assisted as the abductors may be working eccentrically against the resistance of gravity. Therefore to assist motion the fixation is moved in the direction of the required movement. To resist muscle work the fixation is moved in the opposite direction to the required movement and away from the working muscles.

**Distal.** As the ropes are now approaching the vertical over the supporting slings a pendular type of movement will arise.

**Proximal.** Alteration of the point of fixation in this manner results in a movement which rises to its maximum height in the middle of its range, i.e. a reversed pendular movement, and use may be made of this where a multi- or bi-axial joint requires resistance successively in two directions. If the case of the hip joint is again taken, in moving into abduction from adduction, the leg will rise, having resistance in the first part of the range, and fall, the movement being assisted in the second part of the range; on the inward movement from
Fig. 13. (A), (B) and (C). The direction in which the axes of fixation should be moved to assist or resist movement.
CHAPTER 5

Pulleys and Springs and their Relation to the Laws of Mechanics

Pulleys

A PULLEY is a simple machine and gives a mechanical advantage or changes direction of force. The standard types of pulleys and compensating devices are described and illustrated in Chapter 3, and it is now necessary to consider the mechanical features of single and multiple pulleys in order that they may be used to the best advantage.

A single pulley has a mechanical advantage of 1, as the load on the pulley wheel requires an equivalent force to allow it to be balanced. Such a pulley serves to change the direction of force which must be applied in order to move the load (Fig. 16). Use is made of this simple device in the reciprocal

Fig. 16. A pulley circuit with a mechanical advantage of 1.

Fig. 17. A pulley circuit with a mechanical advantage of 2.
abduction to a position of adduction the adductors will be resisted in the first part of the range and the movement of adduction assisted in the second part of the range (Fig. 15).

Combinations of these variations may be used to achieve particular objectives, and great use can be made of these simple laws to obtain the oblique patterns of movement

![Diagram](image)

Fig. 15. When the fixation point is proximal from axial, movement occurs round a reversed pendulum.

which are necessary to re-educate certain muscles adequately. The chief use of these variations of suspension is the facility with which it is possible to pick out a particular group of muscles for work while eliminating opponent muscle work. Grading of work from the minimal effort expended by muscles recovering from early paralysis to the effort expended by muscles capable of performing anti-gravity movements with additional manual or mechanical resistance is possible, and methods of applying such resistances are discussed in succeeding chapters.
by the reduction of friction, which is brought about by the rope moving with the pulley rather than over a fixed surface. When it is desired to perform a weighted movement, resistance may be applied by attaching a known weight to the end of a rope which is arranged over a series of pulleys. Such an arrangement permits the rope to be attached to the patient to give a correct angle of pull for the working muscles, allows the range of movement to be controlled within certain limits, and also puts the moving weight within sight of the patient. This is shown in Figs. 71, 73, 83 and 85.

![Diagram of a pulley system](image)

**Springs**

The types of springs described in Chapter 3 are extensile, the compressive types of springs not being within the scope of this book.

**Elasticity.** A body which is able to regain its original form after it has been distorted by the application of force is said to be elastic. The force applied to an elastic body is known as the stress, and the strain is the quantity of change in size or shape. The relationship of stress to strain is stated in Hooke's Law which states: **The strain is proportional to the stress producing it (so long as the elastic limit is not passed, when permanent deformation will occur).**
pulley circuits which are discussed in detail in Chapter 7, in which the patient raises the injured limb by pulling with the sound limb, working within the limits of his own pain and capacity. The diagram illustrates that a pulley is also a lever of the first order, the pin being the fulcrum and the distance on each side from the pin to the margin of the pulley wheel is the arm or rigid bar, the weight and the force applied are related to one another in the positions indicated in the diagram and alternate in role as the pulley wheel is rotated in opposite directions.

A multiple pulley circuit offers a greater mechanical advantage than a single pulley. This is easily demonstrated if a pulley with an attached weight is inverted and hung from a hook in the ceiling by a cord and a spring-balance inserted into the cord circuit to measure the force (Fig. 17). Each side of the cord takes half the weight, and therefore the mechanical advantage of such a circuit will be 2. If a second pulley is inserted into the circuit so that a downward pull can be applied, then the mechanical advantage is unchanged, the ceiling still takes half the weight but the distance through which the effort moves will be twice that through which the weight moves (Fig. 18). If the weight P is pulled through a distance of 2 ft., the rope A will move through a distance of 2 ft., but the pulley wheel and weight W will move through a distance of 1 ft. as the rope at C will only be shortened by 1 ft.; thus the effort exerted at P is of 2 lb. through a distance twice that through which the 4-lb. weight at W will rise. The velocity ratio of such a circuit is 2, i.e. the effort is applied through twice the distance that the weight is moved. The force is less but is applied for a longer time, and this offers a means of moving a great weight. Such a double-pulley circuit is used in the double rope of the suspension apparatus when it is necessary to gain advantage over the weight of the heavier parts of the patient. This particular circuit achieves a 2 to 1 advantage in velocity ratio, as the distance through which the weight moves is half that through which the applied force moves.

A multiple-pulley circuit may also be used to change the angle of pull without gaining mechanical advantage, except
weight is pushed downwards or raised and then released. The spring will alternately extend and recoil with a decreasing amplitude until it comes to rest in equilibrium. Cessation of movement is due to working against the binding force between the atoms in both parts of the movement, so that ultimately the original force which was produced by the fall of the weight or the supported part is expended (Fig. 19).

Fig. 19 (A) Springs in series. (B) A spring on tension. (C) Springs in parallel.

The weight of a spring. This feature has already been discussed in Chapter 3, but it should be noted that although 50 lb. is the maximum poundage of the heaviest spring normally supplied with a suspension outfit, this does not limit the poundage or resistance which may be applied to resist movement or to balance adverse leverage.

Springs in parallel. If two springs are attached side by side (in parallel) to the same point, the weight of the resistance
The short and long springs described in Chapter 3 possess the property of elasticity in varying degrees. The short springs are made of heavier metal, and their elasticity is consequently less than that of the long springs, which are extremely elastic. This variation in elasticity is used for different purposes—the short, less elastic springs are used to give buoyancy to the supporting medium of a sling, whereas the long springs are more frequently used for their greater extensile property to offer resistance to a one-way movement and, less frequently, for their properties of recoil, which assists one-way movement and oscillation in which a two-way movement is produced.

It should be noted that both recoil and oscillation easily produce passive movement but that extension of a spring requires increasingly powerful muscle work the further the spring is extended. In order to make use of the properties of extensibility, recoil and oscillation, certain points must be borne in mind.

**Extensibility.** A spring must be fixed at one end to allow extension to take place by the application of force at the other end. The force may be the weight of the body resting in a sling and extending the spring or the power of muscle action when the spring is used as a resistance to muscle work.

**Recoil of a spring.** When the force which has displaced a spring from its original position is released a spring will first recoil to its original length and may pass this point. This is illustrated by the "leap" which occurs when a light poundage spring is stretched and released suddenly.

During extension of a spring energy is accumulated and stored as potential energy, as the spring material is elastic. The spring will recoil provided the limit of safe extension has not been passed, converting this stored potential energy into kinetic energy. A proportion of kinetic energy thus released is used in the recoil of the spring as movement, but a proportion will be converted into heat generated by the movement of the molecules of steel on one another.

**Oscillation in a spring.** A spring is attached to a fixed point on a suspension frame or a ceiling, and a suitable weight is hung on the free end of the spring. Oscillation will occur if the
3. *Number of coils.* The rate varies inversely as the number of coils change. Thus a spring with 100 coils will have a rate twice as great as a spring of similar dimensions with 200 coils. This latter point is clearly indicated when two similar springs are loaded in series (Fig. 190). The resultant Load Deflection Graph (Fig. 20) shows that two springs so mounted will have a rate of just half that of a single spring, due to the fact that the number of coils is doubled. The graph clearly shows the change in the "slope" of the load-deflection line.

The Relation of Mechanics to the Use of Springs

Springs are used:

1. As *resistances,* because their ultimate poundage is known. They offer a graded resistance which can be varied by the patient in relation to the state of the working muscle, e.g. a weak muscle will be capable of contracting and working
offered is then the sum of their aggregate poundage (Fig. 19b).

Springs in series. Springs may be attached end to end (in series) and by doubling the length of the spring the poundage resistance will be halved. For example, two 20-lb. springs attached end to end will give 10 lb. if extended by the same amount as a single spring under 20-lb. load (Fig. 190). This fact has given rise to some comment and the following explanation is included by permission of Herbert Terry and Sons Limited, who kindly made a laboratory report on springs of the quality which they supply.

The amount of load required to give a movement (extension) of 1 in. is usually referred to as “rate”. This rate is dependant upon three variables:

1. Wire diameter.
2. Mean coil diameter.
3. Number of coils.

However, variation in rate due to these factors is in such a way that it is not immediately obvious.

1. Wire diameter. The rate varies as the fourth power of the wire diameter. If the spring is made with wire of \( \frac{1}{4} \) in. in diameter, then another one with the same mean coil diameter and number of coils made with wire twice as big in diameter, i.e. \( \frac{1}{2} \) in., the resultant spring will be sixteen times greater in its rate, and this is because of the fourth power law. If you multiply \( \frac{1}{4} \) in. by itself, thus:

\[
0.125 \text{ in.} \times 0.125 \text{ in.} \times 0.125 \text{ in.} \times 0.125 \text{ in.},
\]

the result is 0.0002442 in.; whereas \( \frac{1}{2} \) in. multiplied by itself in the same way, thus:

\[
0.25 \text{ in.} \times 0.25 \text{ in.} \times 0.25 \text{ in.} \times 0.25 \text{ in.},
\]

equals 0.003906 in., which is sixteen times greater than the fourth power of \( \frac{1}{4} \) in.

2. Mean coil diameter. The rate varies inversely as the cube of this dimension, all other conditions being equal. Thus if the mean diameter is halved, the rate will increase eightfold, as \( 2 \times 2 \times 2 = 8 \) and \( 1 \times 1 \times 1 = 1 \), the cube of two is eight times greater than the cube of one.
It should be clearly understood that the patient must play his part by directing his thoughts towards an attempt to contract his muscles at the same moment that he is being assisted; otherwise the movement will be passive. This thought-process is most important; where the thought is, there will the muscle work be; if any effective contraction is available, it will only function in this way. The natural method of progression is first for the movement to be passively assisted as the patient watches the spring, and second for the patient to attempt to aid the spring in lifting the limb as soon as the movement is understood.

3. As an oscillatory medium. When a limb is balanced by the weight of the spring supporting it, an oscillation may be initiated by the operator giving a small passive movement in a downward direction. This applies a slight stretch to the patient's muscles, and as a result of the stretch reflex arising a sufficient stimulus is produced to cause the muscle to contract and amplify the recoil of the spring. A stretch is now applied to the opposing muscle group which contracts and may then amplify the extension of the spring. When such an oscillation occurs the whole movement may of course be passive, but it is frequently found that if the patient assists the alternating movement of the spring the oscillation will continue for a longer period.
against the resistance of a light-poundage spring for a limited number of times, and the range through which movement will occur will decrease as fatigue increases. Thus the effort obtained during successive contractions will always be resisted, but the resistance will gradually be decreased. As the muscle recovers and increases in power an increasing number of resisted contractions will be performed and eventually a spring of heavier poundage can be used.

It should be noted that when a spring is to be used for resistance it should be on slight stretch in the starting position, so that resistance is offered throughout the full range of movement.

2. (a) To assist movement. When muscles are extremely weak or the patient has lost the ability through disuse to contract his muscles it is often necessary to induce the weak muscle to contract. Using the recoil action of a helical spring, a muscle is assisted so that it can lift a limb against gravity; as a natural movement of the joint is obtained at the same time, a true functional movement is simulated. For example, if the arm is suspended in abduction with its weight counterbalanced by a long spring and the arm is passively adducted by the physiotherapist, the following abduction which is obtained is a natural joint movement; or when the leg is suspended and its weight counterbalanced by springs, passive extension at the hip joint will be followed by a natural flexion as the spring recoils. The passive movements given by the the physiotherapist exert stretch on the muscle which facilitates its contraction.

(b) To balance out adverse leverage. This is a particularly useful feature as most of the movements of the human body occur according to the third order of lever, by which the muscle producing the movement works at a mechanical disadvantage. If this adverse leverage can be balanced out with spring suspension, then movement can be produced with a reduced muscle effort without first passively stretching the muscle. In Fig. 21 the weight of the lower leg is counterbalanced by the spring attached to the foot, and therefore as the quadriceps contract the mass of the lower leg is raised with the assistance of the recoil of this spring.
The slings for supporting the arms and the special straps used for the hands and feet should be put on when the patient is in position on the couch.

In all cases, to ensure maintenance of the correct position, there should be an equal length of sling on either side of the limb or trunk. When using the single slings or the special straps the rings that are clipped to the ropes must be exactly central above the limb to be suspended. The rope is held by the ring at the estimated point of fixation, the position is checked by observing the fall of the rope, it is then attached to the hook and the length of the rope is adjusted so that it will just clear the joint to be moved or the centre of gravity of the part to be suspended (Fig. 22a).

If movement is desired the supporting hook should be vertically over the axis of movement; but if support only is desired the hook will be vertically over the centre of gravity.

---

**Fig. 22a.** The method of finding (a) the centre of gravity of the limb; (b) the axis of the joint.

**Fig. 22b.** (a) The cleat in the position for movement. (b) The cleat in position to "hold".
CHAPTER 6

The Technique of Suspension

Care of Apparatus

To keep the apparatus in good condition a little time spent in checking and storing after use will help to ensure efficient technique and prevent accidents and discomfort during treatment. Any knots should be undone and frayed ropes or slings should be sent for repair immediately. To prevent kinking of ropes and wrinkling of slings both should be stored hanging from hooks on a special rack or on the suspension frame. In order that the article required can be easily detached it is as well to have some system whereby each type of rope or sling is always hung in the same place, and different types of either ropes or slings should not be hung from the same hook. Both slings and ropes can be kept clean by regular washing.

General Rules for use of the Apparatus

When using the large slings a double rope is always clipped to either end of each sling, but when using the small slings, as a rule, only one single rope is necessary. Two single ropes are used with the special head sling and one single rope with the special straps for supporting hand and wrist or foot and ankle. Usually the ropes are not attached to the slings until the slings are in the correct position for treatment. Initially the slings are placed in the optimum position for support of each part of the body, and should not be moved after that part has been suspended. It is desirable when treating the trunk, the head and the legs to lay the slings on the couch, the head sling being placed on a pillow or pillows, before the patient lies down and then, if necessary, small adjustments can be made by sliding the slings into the correct position.
ing both ropes attached to the head sling. The arms and forearms are then lifted, next the thighs and lower legs are raised, followed by the thorax and, lastly, the pelvis.

Standard Positions for Slings

<table>
<thead>
<tr>
<th>Part of the Body</th>
<th>Type of Sling</th>
<th>Position of Sling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Special Sling</td>
<td>Occiput in the slot.</td>
</tr>
<tr>
<td>Thorax</td>
<td>Large Sling</td>
<td>Under Scapula.</td>
</tr>
<tr>
<td>Pelvis</td>
<td>Large Sling</td>
<td>Centre under Ischial Tuberosity.</td>
</tr>
<tr>
<td>Thigh</td>
<td>Small Sling</td>
<td>Centre at junction of middle and lower one-third of thigh.</td>
</tr>
<tr>
<td>Leg</td>
<td>(a) Small Sling</td>
<td>Wound in a figure-of-eight round the foot and ankle starting over the lateral malleolus, passing under the tendo achillis, obliquely over dorsum of the foot and then under the instep.</td>
</tr>
<tr>
<td></td>
<td>(b) Three-ring Sling</td>
<td>When using the special foot strap the proximal loop is placed above the malleoli and the distal loop round the instep.</td>
</tr>
<tr>
<td>Upper Arm</td>
<td>Small Sling</td>
<td>Just above elbow.</td>
</tr>
<tr>
<td>Forearm</td>
<td>(a) Small Sling</td>
<td>1. Forearm pronated. The sling is passed under the anterior aspect of the wrist, over the dorsum of the hand, under the palm between the thumb and first finger.</td>
</tr>
<tr>
<td></td>
<td>(b) Three-ring Sling</td>
<td>2. Forearm supinated. The sling is passed under the posterior aspect of the wrist, over the palm, between thumb and first finger and under the dorsum of the hand.</td>
</tr>
</tbody>
</table>

In side lying

<table>
<thead>
<tr>
<th>Part of the Body</th>
<th>Type of Sling</th>
<th>Position of Sling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Special Head Sling</td>
<td>The ear in the slot.</td>
</tr>
<tr>
<td>Thorax</td>
<td>Large Sling</td>
<td>Upper edge in the axilla.</td>
</tr>
<tr>
<td>Pelvis</td>
<td>Large Sling</td>
<td>Centre under the great trochanters.</td>
</tr>
</tbody>
</table>
of the part to be suspended. The ropes are clipped to the slings and the length adjusted by holding the cleat horizontal and then sliding it along the rope. The apparatus is then checked to ensure that all parts are in the correct position.

When adjusting the length of the ropes, either for raising or lowering the patient being treated, the cleat should always be moved when it is horizontal, as this allows the rope to slide freely through the holes. To fix the length of the rope the cleat should be turned until it lies nearly vertical, so that the friction between the rope and the cleat will prevent slipping (Fig. 23a, a and b). If necessary, the rope may be shortened by pulling the free end through the cleat and making a knot that will neither slip nor become so tight that it is difficult to untie. Fig. 23a, a and b show methods of making such a knot.

The proximal part of the limb should be elevated first and then the distal part, then to complete the suspension both proximal and distal parts can be lifted simultaneously. When suspending the whole body the head is raised first by shorten-
which, except for the head, will be above the centre of gravity of each part. The hooks suspending the head and the trunk should be sufficiently wide apart to prevent lateral compression by the slings when the patient is suspended.

The points of suspension will be as follows:

1. **For the head**—on a line at the level of the suprasternal notch at right angles to the long axis of the body.

2. **For the thorax and pelvis**—on a line through the centre of gravity of thorax and pelvis respectively, at right angles to the long axis of the body.

3. **For the arms**—above the centre of gravity, calculated to allow the arm to lie in a few degrees of abduction.

4. **For the thighs**—above the centre of gravity for each thigh, allowing for slight abduction at the hips.

5. **For the legs**—above each ankle, allowing for slight abduction at the hips.

Both ropes may be clipped to the head sling, and one rope clipped to the thoracic sling and one to the pelvic sling at the same side of the couch. The slings and straps for supporting the arms and the feet may be clipped to the ropes but looped out of the way. The patient is then brought to the side of the couch from which the ropes have been looped back and is asked to sit on the pelvic sling or, if necessary, is assisted into position. As he lies down his head is guided into the head sling and his legs are assisted into place on to the thigh slings. The small slings or special straps are slipped round the feet and arms, and all slings and straps are then clipped to their respective ropes. Any necessary adjustments are made to ensure correct position of slings and ropes, and the patient is now ready to be suspended in the manner already described (Fig. 26). The blanket covering the couch can now be wrapped loosely round the body and legs to keep the back warm, and if necessary another light blanket may cover the front of the body.

**Technique for Axial Suspension**

When suspension is used with the aim of encouraging movement axial support is chosen. This will apply when movement
When the whole, or any part of the body is suspended the joints should be in a position of very slight flexion, with the limbs and trunk as a whole lying horizontally just clear of the couch.

During the preparation and before any part is actually suspended, the procedure is explained to the patient and he is asked to relax and allow himself to lie as if in a hammock.

**Fig. 24. (A and B) A single sling used in figure of eight.**  
**C** A three-ring sling to support the foot.

**Fig. 25. (A and B) A single sling doubled, used in figure of eight.**  
**C** A three-ring sling to support the hand.

**Technique for Vertical Suspension**

The technique for total suspension will be described, but if part of the body only is to be treated, the same local technique will apply. When preparing for total suspension an unfolded blanket is placed over the plinth and a pillow or pillows placed in position for the patient's head. The head sling is laid on the pillows, the two body slings and two thigh slings are placed in suitable positions on the couch. All the ropes are hung from hooks on the overhead support at points
Fig. 27. Axial fixation to permit flexion and extension of the leg.

Fig. 28. Axial fixation to permit abduction and adduction of the leg.
is required about one axis in one joint, i.e. at the hip joint alone and also if movement is required in more than one joint at a time, as in spinal movements. In the latter case the mean axis is chosen about which the desired movement will take place. If the aim of treatment is to encourage movement in the lumbar region for flexion and extension, the mean axis will be slightly higher than for lateral flexion. If the thoracic spine is to be moved, then it is wise to arrange the mean axis in the upper half of the thorax in order to encourage movement of a part which is frequently stiff, and so help to inhibit movement of the more mobile lower thoracic and lumbar regions.

The starting position must be chosen to allow movement in the horizontal plane and to enable those parts of the body that are not moving to rest securely on the couch. For example, abduction and adduction are performed in lying, flexion and extension in side lying, and oblique movements with the patient's body turned to the necessary angle from the horizontal (Figs. 27 and 28).

Fig. 26. Total suspension showing vertical fixation for all points of the body except the head.
sling is clipped a rope which is fixed above the joint to be moved. To the other ring is fixed the spring or weight and pulley circuit that will offer resistance. The sling will not slip provided the "vertical part" attached to the supporting rope is lateral to the "horizontal part" attached to the resistance. If this method is used, resistance can be given in the plane of the movement without applying two slings (one to support and one fixed to the resistance) (Fig. 29).

![Fig. 29. A method of applying resistance to a suspended movement (devised by the staff and students of the Sheffield School of Physiotherapy).](image)

Many of the well-known methods used for building muscle power and endurance by the use of controlled loads, repetitions and repetition rates can be adapted for use with suspension at this stage.

**Tests for Muscle Power**

It is usual to classify muscle strength by finding out if a muscle can work against gravity and then to see how much resistance can be offered. When a muscle is classed as 1—unable to withstand the force of gravity—other available tests can detect a "twitch", but with the aid of suspension apparatus it is possible to use several tests which are useful in assessing the sub-gravity state. They are named as follows:
The patient is therefore placed in the suitable starting position and the point of support (vertically above the axis of movement) is found by holding the rope so that the lower end hangs above the joint at which the movement will take place. If assistance to movement or resistance to muscle work is required, the fixation will be shifted laterally on a line passing over the axis of movement at right angles to the long axis of the body (see Chapter 4).

Technique for Applying Mechanical Resistance to a Limb in Suspension

Springs or weight and pulley circuits combined with suspension provide a very useful means of building up muscle power and are particularly effective when a muscle or muscle group has reached the stage of recovery graded as 2, i.e. has control of the limb with gravity neutral. Graduated resistances up to the actual weight of the limb can be applied so that the muscle or muscles concerned may undergo a training programme that will build up power until the next stage or grade 3 has been reached, by which time the limb can be lifted against gravity and suspension therapy may be discontinued.

The limb to be treated must be suspended by axial support, and the resistance must be applied so that as the muscle concerned shortens, the spring is stretched or the weight is raised. The usual principles governing the application of mechanical resistances must be borne in mind, and therefore the following points must be noted:

1. The angle at which the rope or spring is applied.
2. The point at which the resistance is attached.
3. The poundage and tension of the spring or the poundage of the weight (see Chapter 7).

The following useful method for fixing the resistance to a limb in suspension was devised by the staff and students of the School of Physiotherapy, Sheffield.

The sling is wound round the limb and to one ring of the

* Oxford grading.
weight and pulley circuit is attached to the limb and the amount the muscle or muscles can lift is noted. Obviously the weight used at this stage must not exceed the weight of the limb (see Fig. 32, average weight of parts of body). A spring is not suitable for testing progress, as it is difficult to ensure that the tension is always exactly the same on each occasion.

Muscle Control

If muscle control is the main aim, treatment may start by moving the fixation in the direction of movement. This will assist the motion and re-educate kinesthetic sensation and
1. Oscillatory.
2. Distance.
3. "Halt."

All these tests give valuable information. It is on such information that exercises for re-education by weightless movement should be carried out.

When testing the lower limb for power in abduction and adduction the leg is suspended by axial fixation above the hip.

1. Oscillatory test. The operator gently swings the leg out of the mid-line (about 12 to 18 in.) and counts the number of oscillations the limb makes before it comes to rest. The usual result in a paralysed limb is about 8 to 10 to-and-fro movements. The swing is now repeated and the patient is asked to help the movement. If there is some power in the muscles, the number of to-and-fro movements will exceed ten.

2. Distance test. The patient is asked to move the limb once only in one direction and the operator returns it to the zero position. The limb is then moved in the opposite direction and returned to zero in the same way. The distance that the limb travels from the mid-position (or zero) by the patient's own effort gives some indication of muscle power (Fig. 30).

3. Halt test. The patient swings the limb to and fro and on the command "halt" or "stop" the swing is stopped.

The length of the latent period which so often occurs between the command and the patient's ability to apply the brake will decrease as control and power return. Further, if the command is given at the limit of the arc, the ability to halt before the limb returns to zero or mid-position shows that the muscles, that should produce that particular arc of movement, are in fact working and momentum is not solely responsible for the movement.

When the muscle or muscle group is classified as 2 (movement with gravity neutral) progress towards 3 (movement against gravity) can be charted if graduated resistance is applied to the limb. The suspension should be axial, and a
mechanical resistances must be observed. Measurements of muscle power by using graded weights (not springs) are made at suitable intervals and the load increased as the strength returns. When the patient is able to lift the limb against gravity suspension will no longer be required as a means of retraining the affected muscles.

**Technique for Mobility**

In cases where mobility is the main aim of treatment it is recognized that active muscle work is the most effective means of restoring elasticity and stretching contractures. But the memory of the movement pattern will have become clouded and the muscles concerned weakened through disuse. The mechanical and physiological factors operating on a suspended part facilitate localization of movement, since that joint is easier to move than the rest of the body and the fixator muscle work is lessened. For these reasons suspension therapy is of value in the treatment of stiff joints.

As previously stated, the idea of movement can be retaught by suspending in order that gravity and momentum may assist, and in the early stages of treatment it is permissible to make use of these factors. The limb is therefore suspended by axial support with the suspension point shifted laterally in the direction of required movement, and the patient is instructed to make as much effort as possible in that direction, but the swing may be quicker than when treatment is being directed to muscle training only. Throughout, the physiotherapist, by tone of voice and command, must direct the patient's attention to the required movement. Attention to relative stability of other parts of the body is particularly important, as the outside forces of gravity and momentum are liable to cause movement in other joints, e.g. if abduction in one hip only is desired, the contra-lateral leg must rest firmly in abduction to prevent tilting of the pelvis and movement in the lumbar spine. Suspension of the leg will also free the physiotherapist to give manual assistance to the required movement, therefore as the patient is approaching the limit of voluntary abduction in the affected leg, one hand can give pressure in the
eccentric control by the Antagonists, but to ensure active shortening of the Prime Movers the fixation must be true axial or shifted laterally in the opposite direction to the required movement. When using suspension for muscle training it is essential to ensure that the movement is being produced by the Prime Movers and not by momentum. The patient will therefore be instructed to think of the required movement and to perform it slowly, as momentum can produce the same arc of movement if the antagonists are allowed to contract and then relax quickly. Manual control to prevent the limb being carried too far in the opposite direction by the antagonists and palpation of the agonists are also necessary to ensure that the muscles under treatment are in fact producing the movement. Manual control may also be necessary to limit the range of movement. As power returns, the fixation may be shifted laterally to oppose the movement, gravity will now offer slight resistance but unless the same precautions are taken as in using true axial support it is possible for momentum to carry the limb upwards. Progression in work for weak muscles can be given by increasing the lateral shift of the fixation point, but the distance of the lateral shift must be limited as a point will be reached where the limb will be moving in such a way that the specific muscles are no longer working. For example, if the hip abductors are being treated and the fixation point is being moved towards the opposite side of the body, a point will be reached when the hip will flex and rotate and not abduct, as the leg is lifting and not moving sideways.

Increase in work for the recovering muscle group (i.e. hip abductors) can now be given by resuming true axial support over the hip and applying a mechanical or manual resistance to the movement of abduction.

In order to teach the patient the "feel" of working against an increasing load it is wise to start by offering manual resistance to the movement, but when the necessary effort is appreciated some form of mechanical resistance by spring or weight and pulley is more efficient as, provided adequate teaching and supervision are given, the patient may practise for stated periods on his own. The rules for the application of
CHAPTER 7

The Application of Springs and Pulleys to Movement

Care of Apparatus

Springs. The life of both short and long tension springs may be extended if care is taken during their use and storage. The springs should be stored lying flat and are most conveniently kept in suitably labelled racks. Care should be taken when putting the springs into the racks that the clips do not catch on adjacent springs, so causing buckling. The poundage tabs should be inspected at intervals to see that they are firmly fixed and replaced when necessary. If the poundage tabs are lost, then the poundage of the spring may be ascertained by applying known weights to the spring until the inner cord is fully stretched. The split clips on the long springs may be stiff and difficult to use at first, and the method of putting a sling or ring on to the split clip is illustrated in Fig. 31A. A slim screwdriver or pair of scissors may be used to separate the components of the split clip in order to remove the slings, as illustrated in Fig. 31B.
direction of abduction whilst the other hand stabilizes the opposite leg. Since the hip adductors (the antagonists) are still reciprocally lengthening as the abductors (the prime movers) are shortening, a mechanical stretch will be superimposed on a physiological lengthening.

However, as range of movement and active control improve assistance will be lessened; the fixation point will be brought inwards until it is vertical over the hip joint and the amount of assistance given by the physiotherapist will decrease.
The physiotherapist uses springs and pulleys in many ways when giving movement to a patient. It will be found that certain rules relating to the application of force must be observed and are common to the use of both springs and pulleys.

When the force of a spring or a pulley circuit is attached to the body the angle of attachment is an important factor if the most economical use is to be made of the available forces. The principle of the parallelogram of forces applies to body movement and may be considered here in two ways:

1. The most efficient angle at which a muscle can pull on a bone is one of 90° and parallel to the movement, as then all energy is expended in producing the desired movement. When the angle between the working muscle and the bone is greater or less than 90° some of the energy is expended in either approximating or separating the joint surfaces.

2. Thus when we apply an external force to a moving bone the same law relating to the most economical use of force will operate. Therefore when force is applied either to assist or to resist a movement it should be as nearly parallel with the line of movement as possible. However, as the limbs of the body describe an arc of a circle during movement, it is possible only to observe this rule at one point on the arc. Therefore when applying force to a moving limb this point should be in the centre of the arc of movement which is in use. In this position the force will be most nearly parallel to all parts of the arc. From the accompanying Figs. 33A and B it will be seen that when force is applied to this point in the form of either a spring or a rope (pulley circuit) the rope or spring will be at right angles to the moving limb when it is in the centre of the arc of movement (Fig. 34). This applies whether the force resists or assists the movement.

Resistance for more than one joint—as in arm and leg thrusting or retraction:

In these cases the path of movement is along a straight line and therefore if the resistance is applied parallel to the long
The short tension springs have no guiding rope down their centre and consequently it is important that they are not overstretched in use, but as accurate work is not performed against their resistance it is not essential to know their exact poundage. When using the short tension springs for buoyant suspension it is advisable to err on the side of over-estimating the weight of the body in relation to the poundage of the spring, in order to prevent overstrain and distortion. When using the long tension springs it is inadvisable to bend them round the corner of the bed or frame as this rapidly produces distortion and moreover does not allow the full poundage of the spring to be used, so that a large degree of accuracy is lost. It is also inadvisable when the springs are used in parallel to allow them to lie in juxtaposition to one another, so that when they are extended and the coils separated they can interlock. Interlocking can be prevented by the use of small metal spreaders (Fig. 6d).

Pulleys. The primary concern of the physiotherapist in the maintenance of pulley circuits will be to see that the pulley is occasionally oiled so that it runs smoothly and friction is reduced to a minimum and, most particularly, to check that the ropes are running freely and are not badly frayed.
the method of applying resistance by springs to a movement which will occur through a range of 90° or less, and it will be noted that with such a range of movement it is possible to arrange the spring resistance so that the desired angle of 90° in the middle of the range is easily obtained.

When the range of movement is more than 90°, as, for example, in the knee joint, it is difficult to obtain a starting position for the spring which allows resistance at an angle of 90° in the middle of such a very large range and at the same time gives unimpeded movement to the spring and resistance at all parts of the movement (Fig. 35c). It will be found that to obtain a satisfactory angle of resistance it may be necessary to divide the movement into two or three ranges, and use may be made of this division when it is particularly desired to work a muscle in a specific range (Fig. 35a and b).
Fig. 33. (A) The force is attached to the limb at an angle of 90° in the middle of the range of movement. (B) If a 90° angle of attachment of force is to be achieved at all parts of the arc of movement, the fixed point must constantly be moved.

axis of the straight limb it will also be parallel to the path of movement. The illustrations (Figs. 34 and 35A and B) show

Fig. 34. A method of fixation for resisted extension of the leg.
Abduction and adduction. The patient is in sitting with the spring unit attached at the centre of gravity of the arm so that it is held in some degree of abduction according to the possible range. It is more satisfactory if the spring unit is attached to the overhead point so that at first the arm is abducted in the anatomical plane. This is usually achieved if the patient interlocks the fingers, as shown in the diagram, and later abduction in more flexion or more extension may be attempted (Fig. 36a).

![Diagram](image)

Fig. 36. (A) A method of fixation for oscillatory flexion and extension of the arm. (B) A method of fixation for oscillatory abduction and adduction of the arm.

2. For the leg. Movement may be obtained at the hip joint in flexion and extension or abduction and adduction.

Flexion and extension. With the patient in back lying a three-ring sling is attached to the ankle and foot and the spring selected should lift the limb into slight flexion. The fixation point should be over the hip joint in order to give an angle of 45° between the leg and the spring. At this angle it will be found that the knee will not tend to hyper-extend as much as if the rope is too vertical or too oblique (Fig. 37). Both legs may be treated together on the same spring unit or separately on different spring units.

Abduction and adduction. The patient is in side lying.
Examples of the use of springs as resistances to various parts of the body are described in Chapters 8, 9, 10 and 12.

To obtain oscillatory movement. This technique is of value to re-train the idea of movement, but great care must be exercised in the selection of cases. The patients enjoy the feeling of again moving, but as repetitive movements are liable to irritate joints, control of the length of treatment is also important.

A short or long spring unit may be used with springs of sufficient poundage to counterbalance the weight of the limb and lift it into the desired starting position. Provided the limb is satisfactorily counterbalanced by the spring, which should be slightly extended when the limb is resting, a satisfactory oscillation can be set up by a passive downward movement given by the physiotherapist, thus applying further extension to the spring. As explained in Chapter 5, the spring will recoil when the downward pressure is released, thus lifting the limb up to and beyond its position of rest. When the accumulated energy in the coils of the spring has been expended and the spring is no longer lifting the limb, gravity will cause it to fall and the spring will again be extended. This type of movement is at first passive, but in each part of the movement a slight stretch is exerted on the muscles alternately which may be sufficient to facilitate an active contraction by the patient. With encouragement, the patient will thus be stimulated to maintain the original amplitude of the oscillation or to increase the number of to-and-fro movements so that the movement ultimately becomes one of activity.

1. For the arm. Movement may be obtained at the shoulder joint in flexion and extension or abduction and adduction. It will usually be found more satisfactory to suspend both arms simultaneously and allow the patient to perform a bilateral movement.

Flexion and extension. The patient is in back lying with a spring unit supporting the arm at its centre of gravity and lifting it into slight flexion. The fixed point of attachment of the spring should be at a suitable point above, depending on the possible range of movement (Fig. 36a).
The patient is then carefully instructed to perform a movement in the desired direction, timing it with the recoil of the spring and using the agonists (Figs. 36A and B; 37 and 38).

**Standard Techniques for the Use of Pulleys**

For purposes of exercise pulleys may be used in two ways:

1. A pulley and rope system, usually termed a reciprocal pulley circuit (Fig. 39).
2. A pulley and weight system.

![Fig. 39. A reciprocal pulley circuit.](image)

1. **A reciprocal pulley circuit** is of great advantage because it makes the patient co-operate in his own treatment. He performs the movements entirely by himself and controls both the amount of self-traction, self-resistance or self-assistance. The exercises given with a pulley and rope system are all double sided and the movements are always reciprocal.

**Techniques.** It should be stressed to the patient that considerable co-ordination is required to perform movements
(n.b. Only one leg can be treated at a time.) A three-ring
sling is attached to the foot and ankle and a spring selected
which will lift the leg into slight abduction. Again the point
of fixation is at a $45^\circ$ angle to the limb (Fig. 38).

To assist movement. In certain cases springs are of value to
assist muscles to perform movements both when the muscles
are too weak to move the weight of the part or when the
range of movement is limited. Great care should be exercised

![Diagram of oscillatory movement](image)

Fig. 37. A method of oscillatory flexion and extension of the leg.

Fig. 38. A method of fixation for oscillatory abduction and adduction of the leg.

in using this method to ensure that the muscles concerned
are, in fact, working, as the recoil of the spring can be en-
tirely responsible for the movement which may be passive or
directed by the antagonists working eccentrically.

A spring unit is attached so that the recoil of the spring
acts in the direction of the desired movement. The amount of
tension on the spring should be adjusted so that when the
agonists have contracted and the limit of desired range is
obtained slight tension still exists in the spring. The limb is
first taken into the reverse position either passively by the
operator or actively by the patient working the antagonists.
APPLICATION OF SPRINGS AND PULEYS TO MOVEMENT

of the sound limb, but if there is slack in the rope this effect is lost.

4. Careful supervision of the exercise is essential at all times as it is easy for the patient to fall into bad habits.

Progression may be achieved as follows: The patient may be "introduced" to the apparatus to gain confidence, by performing slow, small range movements within the limit of discomfort. As confidence increases the range may be increased.

1. Active assisted movement. The good limb may do most of the work and the injured one is raised within the limit of discomfort and returns by its own weight controlled by the good limb through the rope circuit. This type of movement is performed slowly and the sound limb may exert traction via the rope on the affected limb.

2. Active thrusting action getting maximum movement in the injured limb. The patient will be instructed to decrease the assistance given by the sound limb and to increase the thrusting power. The patient is also instructed to hold in the maximum stretched position simultaneously releasing the tension of the rope with the sound limb. The co-ordination required for the alternate thrusting movement is not easy to learn and must be closely supervised.

3. Active bilateral movements in small ranges done with even rhythm gradually increasing the speed. When excessive inhibition of movement exists, this method is of value as it tends to confuse the patient's sense of position of the limb in space. It is often found that at the end of a short treatment the range has considerably increased.

2. Pulley and weight system. In such a system the pulleys are used merely to change direction of force and offer a convenient method of grading resistance for many movements. The patient is encouraged to further effort by the gradual increase in the weight that he raises, and as with the pulley and rope system, can to a certain extent control the effort he is making. It should be noted that with such a resistance the dead weight is applied to all parts of the movement, though the resistance varies with the angle of the rope as the limb moves.
with a pulley and rope, as the rope must be kept taut and the exercise should be performed smoothly. The following points must be considered:

1. The relative position of the pulley and the patient. Both pulley and patient must be arranged carefully in order that the force is applied at the required angle, and as the range of

movement increases it will be necessary to adjust the relative positions of one to the other (Figs. 40 and 41).

2. The patient's starting position should be based on the usual remedial rules and should eliminate trick movements.

3. Adjustment of the rope—the rope must be taut, e.g. in exercising the shoulder the injured limb will be placed in the bend position which allows for an easy start, while the sound limb is fully stretched. As the arms change position the injured limb is raised and its excursion is assisted by the descent
(Fig. 42.) The position of the "stop" must be carefully arranged so that it touches the pulley as the part reaches the resting position. Alternatively the length of the rope may be such that when the moving part reaches the resting position the weight rests on the floor.

**Method.** There are many schools of thought on the weighting, timing and repetition of loaded muscle work and a discussion of the various techniques advocated is not within the scope of this book. But in most cases one common feature emerges—the patient must obtain maximum possible shortening of the muscle.
With the development of techniques of direct loading of muscles the need for pulley and weight systems is decreasing; some techniques have been described as there are times when a weight and pulley is a useful form of resistance, and the authors consider that they are the most efficient method of offering known resistances to movements which are performed in suspension. Information on the power of a muscle, which is incapable of performing an anti-gravity movement, may be obtained only by testing in suspension with a weight and pulley, or by an accurate spring balance. Direct loading in suspension is very difficult to control as momentum distorts the muscle work.

Technique. 1. The starting position should be based on the usual remedial rules to avoid trick movement and to allow the required range of movement.

2. The relative position of the pulley and the patient. Both the pulley nearest the moving part and the patient must be arranged so that the rope is at an angle of 90° to the moving part when it is in the middle of the range of movement being practised.

3. The Weight, (a) should be selected in accordance with the particular aim of treatment and the known capabilities of the working muscles; (b) must travel freely and if possible should be near enough to allow the patient to alter the resistance himself; and (c) it is also desirable for the patient to be able to watch the moving weight, so that he may be aware by what he sees as well as by what he feels that he is obtaining the maximum range of movement.

Fig. 42. The "stop" for use in pulley and weight circuits.

4. The stop. In some circumstances it may be desirable to relieve the part of the weight when it is in the resting position. To achieve this a wooden "stop" may be inserted in the circuit between the moving part and the pulley nearest to it.
range of movement is the same if the elbow be flexed or extended, provided the velocity remains the same.

However, as soon as the stage has been reached when resistance is necessary the laws of leverage will operate and the angle at which resistance is applied must be considered, in order that work may be graded accurately.

Therefore when using suspension for the re-education of movement, though the mechanical aspect is important, the complex physiological factors concerned in functional movement of the body should always be considered.

In the following pages some of the movements are described that are most commonly re-educated satisfactorily in suspension. However, if the fundamental principles are understood, re-education in suspension can readily be applied to most parts of the body.

**FOR MOVEMENT OF THE UPPER LIMB**

*Shoulder Movements*

It is sometimes desirable to localize abduction or external rotation to the humeroscapular joint, particularly when the muscles performing these movements have been weakened as a result of disuse or injury to their motor supply, but, as far as possible, the functional position and actions of the rest of the limb during that particular movement should be considered. Therefore, when concentrating on either of these movements in the humeroscapular joint, the humerus should be in such a position that it lies in line with the spine of the scapula. The elbow should always be extended; and the forearm allowed to rotate with the humerus when rotation is required.

**Abduction.** The patient from lying turns through 10–15° towards the affected arm, which is suspended axially above the humeroscapular joint so that the humerus will lie in 10–15° of flexion with the sagittal plane of the thorax. The elbow is extended and the position of the trunk maintained by placing pillows behind the head and shoulders (Fig. 43). The action of the deltoid can be reinforced by instructing the patient to stretch the arm as if reaching for an object whilst attempting to raise it from the side. In the early stages it may
CHAPTER 8

The Application of Suspension to Movement

Introduction

The functional aspect of movement is an important principle that should not be forgotten when suspension is being used to treat conditions that require re-education of movement. In previous chapters it has been pointed out that localization of movement to a specific joint is readily achieved by suspending the limb distal to that joint. Although localization of movement and accurate muscle work may be desirable, it should be remembered that certain combinations of movements and the position of adjacent parts of the body will facilitate the particular movement required. In other words a functional movement pattern, such as trying to touch an object in sitting or standing, will often result in a greater range of movement in a stiff shoulder than concentration on trying to perform pure abduction in lying.

The physiological value of bilateral movement in helping a patient to regain the feel of a movement pattern is well known. Though it is not possible to suspend both limbs in all basic positions and though the accurate grading of work cannot always be effected, bilateral movement in suspension is often of value when limb movement is impaired.

A long weight arm will increase “work” if movement is performed against gravity, but, when the limb is suspended and therefore “weightless”, the length of the moving lever does not influence the work being done by the muscles producing the movement, once inertia has been overcome. Using movement at the shoulder to illustrate this point, work for the deltoid is greater when lifting the arm against gravity if the elbow is extended, but when the arm is in axial suspension, the work done by the deltoid in maintaining a known
range of movement is the same if the elbow be flexed or extended, provided the velocity remains the same.

However, as soon as the stage has been reached when resistance is necessary the laws of leverage will operate and the angle at which resistance is applied must be considered, in order that work may be graded accurately.

Therefore when using suspension for the re-education of movement, though the mechanical aspect is important, the complex physiological factors concerned in functional movement of the body should always be considered.

In the following pages some of the movements are described that are most commonly re-educated satisfactorily in suspension. However, if the fundamental principles are understood, re-education in suspension can readily be applied to most parts of the body.

FOR MOVEMENT OF THE UPPER LIMB

Shoulder Movements

It is sometimes desirable to localize abduction or external rotation to the humeroscapular joint, particularly when the muscles performing these movements have been weakened as a result of disuse or injury to their motor supply, but, as far as possible, the functional position and actions of the rest of the limb during that particular movement should be considered. Therefore, when concentrating on either of these movements in the humeroscapular joint, the humerus should be in such a position that it lies in line with the spine of the scapula. The elbow should always be extended; and the forearm allowed to rotate with the humerus when rotation is required.

Abduction. The patient from lying turns through 10–15° towards the affected arm, which is suspended axially above the humeroscapular joint so that the humerus will lie in 10–15° of flexion with the sagittal plane of the thorax. The elbow is extended and the position of the trunk maintained by placing pillows behind the head and shoulders (Fig. 43). The action of the deltoid can be reinforced by instructing the patient to stretch the arm as if reaching for an object whilst attempting to raise it from the side. In the early stages it may
be necessary for the physiotherapist to stabilize the clavicle and scapula by using her hands to assist the fixator muscles. Later, as the patient learns to co-operate more fully, if required, assistance to stabilization may be added by passing a long strap or bandage over the shoulder and under the foot. If treatment is being given to strengthen weak abductors, as a preliminary measure, the suspension point may be shifted towards the patient's head in order that the "movement" of abduction may be assisted, but the patient must still be instructed to think of raising the arm sideways in order to restore or retain the memory of that movement pattern. The sound arm may also be suspended so that bilateral movements can be used to help in the restoration of the "feel" of abduction. The patient will be in lying with both arms suspended and lifted into about 10° of flexion at the shoulders, so the movement will not be pure abduction but abduction with extension.

The next step will be to suspend the arm by axial support over the shoulder, and, as active control in this position improves, the suspension point should be shifted towards the
feet in order that gravity may resist the muscle action. When the movement becomes distorted, so that the patient is flexing rather than abducting the shoulder, a resistance other than gravity must be applied. The fixation is therefore returned to axial, instructions to reach out and raise the arm from the side are repeated, whilst the physiotherapist applies manual resistance. As soon as the necessary effort has been appreciated a spring or weight and pulley may be attached to the wrist or upper arm, and the mechanical laws of leverage and angle of pull will now obtain. As soon as the arm can be raised against gravity suspension therapy will no longer be required.

Fig. 44. Arm rotation in side lying.

Rotation. From side lying the patient turns through 10–15° towards lying with the arm, extended at the elbow, in approximately 90° of abduction and 10–15° of flexion to the thorax. As before, pillows will help to steady the head and shoulders. If the finger flexors are active, the patient can grip the strap during treatment and so associate a natural action of hand and forearm whilst concentrating on rotation at the humeroscapular joint (Fig. 44). The point of fixation is
vertical to the long axis of the arm which is suspended by attaching a three-ring strap to the wrist and palm.

When the rotary movements are performed in this position the weight arm is short and, consequently, the arc of movement very small, therefore technically it is not possible to achieve an accurate grading of effort by altering the suspension to obtain a movement against gravity, and for the same reasons other mechanical resistances cannot be satisfactorily applied. However, as a means whereby control of rotation can be taught this technique has been found to be helpful.

Other movements. Flexion and extension will be performed in sitting (Fig. 45) and elevation through flexion in side lying.

Scapular movements. In cases where muscle control of the scapula is affected suspension is useful to re-educate the forward thrust and the upward movement of the arm into elevation. For forward thrusting the patient may be in side lying or in sitting with the arm supported by two slings or a three-ring strap and sling as shown in Figs. 46A and B.

For the practice of elevation it is best to have the patient in prone lying with a 10–15° turn towards the affected limb. The arm will then move upward in a functional plane and the physiotherapist will be able to observe and if necessary control the scapula. Again spring or weight and pulley resistance can be applied as power returns (Figs. 47A and B).

Oblique and combined movements. Oblique movements combined with rotation can be practised with the patient turned to a suitable position to allow the required movement
Fig. 46. Forward thrusting:
(A) In sitting (resisted);
(B) In side lying.

Fig. 47. (A) and (B) Elevation of the arm in forward lying.
to take place in the horizontal when the limb is axially suspended.

However, to allow rotation to occur simultaneously with the other movements a single sling and reciprocal pulley circuit must be used to support the arm. The forearm rests in the single sling to either end of which are clipped the ends of the pulley circuit. As the limb rotates it rolls in the moving sling and there is no friction between the limb and the sling. This method of suspension is illustrated in Fig. 48. The general rules for grading of effort discussed in Chapter 6 and referred to in the description of re-education of simple abduction will apply.

![Fig. 48. Suspension with a pulley circuit to permit combined rotation with abduction and adduction of the arm.](image)

**General Arm Movements**

When there is a general limitation of movement resulting from chronic stiffness of all the joints in the upper limb, movement of the whole arm in a small range is possible. The patient may be placed in half lying and both upper limbs are suspended by axial support over humeroscapulae and elbow joints, both shoulders and elbows being slightly flexed. Associated flexion of elbow, extension of shoulder and retraction of scapula, or vice versa, can then be practised in a small range. Since the limb is suspended the fixator muscle work and the effort required to produce movement will be lessened. The resulting movement, though frictionless, will
not take place in a horizontal plane, as the suspension point for the elbow will not remain truly axial.

**The Elbow, Wrist and Hand**

Though suspension therapy may be used to treat limitation of movement at the elbow, the obliquity of the axis of movement makes it impossible to obtain a pure horizontal movement of the forearm if the upper arm is held still. However, if concentration on either flexion or extension is required for some specific purpose, the upper arm may be supported by vertical suspension and the forearm and hand by axial suspension over the elbow. The shoulder should be in extension if flexion is the required movement at the elbow, and in flexion if the elbow is to be extended (Fig. 49A and B).

**Wrist and fingers.** Partly because the parts moving are relatively small, and partly because the movements of wrist and fingers are so closely related that localization is undesirable, suspension therapy is not generally used in the re-education of hand movements.
CHAPTER 9

The Application of Suspension for Movement in the Lower Limb

Suspension therapy is of great value in the treatment of hip conditions as, broadly speaking, it may be said that the natural hip and knee movements are relatively less complex than those in the joints of the upper limb; and repetitive movements, so easily obtained in suspension, do not irritate the hip in the same way as they so often seem to do when the shoulder or elbow are treated in this way.

Hip Treatments

When giving treatments for the hip the patient will be in side lying for flexion and extension and in lying for abduction and adduction.

If one hip is to be treated, the contralateral leg must be placed in such a position that it will help to hold the pelvis steady and so prevent movement "overflowing" into the lumbar spine. Therefore the starting positions will be as follows:

- **Abduction**—the opposite leg fixed in abduction (Fig. 50).
- **Adduction**—the opposite leg fixed in adduction.
- **Extension**—the opposite leg fixed in flexion (Fig. 51).
- **Flexion**—the opposite leg fixed in extension.

Bilateral suspension is useful for performing abduction if both hips are affected, and in certain cases it is also useful if only one hip requires treatment. For technical reasons it is impossible to obtain full range contralateral flexion and extension in both hips at the same time. When treating one leg if either flexion or extension of the hip are required, it is often helpful to include the associated knee movement. Therefore,
Fig. 50. Axial fixation to permit abduction and adduction of the leg.

Fig. 51. Axial fixation to permit flexion and extension of the leg.
with the patient in side lying, the thigh may be supported by axial suspension above the hip and the foot and lower leg by axial suspension above the knee. Combined hip and knee movement will then take place but, as in the case of combined elbow and shoulder movement, the plane of knee movement will not be horizontal throughout. However, the natural combination of flexion, followed by extension, at both joints will often assist in the restoration of some mobility in cases where there is gross limitation of hip movement.

If it is necessary to stretch contracted structures at the anterior aspect of the hip, momentum can be of value. The knee should then be kept straight throughout, if necessary by the addition of a light splint. Both ropes will then be fixed to a point above the axis of movement of the hip. This technique may also be used if stretching of the hamstrings is required.

Manual assistance to stretch contracted structures can be given very easily when either both legs or one leg only is suspended. The following technique has been found useful in cases where hip extension is limited. Supposing the left leg is to be treated, the patient will lie on the right side, the right leg being flexed at hip and knee, the left leg will be suspended either axially above the hip joint or, if extra assistance to movement is desired, to a point posterior to the axis of movement. The physiotherapist stands at the foot of the couch and places the left knee under the sole of the right foot to keep the right leg in flexion. The left hand is placed on the medial aspect of the right knee to keep the leg flat on the couch, and the right hand exerts pressure over the front of the left thigh as the patient reaches the limit of voluntary extension.

If abduction is limited and one leg is suspended, one hand stabilizes the resting thigh whilst the other hand exerts pressure on the moving limb as the limit of voluntary abduction is reached. When both legs are suspended pressure will be exerted on the medial aspect of both thighs at the end of the movement. If necessary, additional fixation can be supplied by using sandbags or by tying a sling or bandage in such a way that it will hold the resting thigh steady. Provided the patient has adequate use of hands and arms a firm bandage or sling passed under the resting thigh and held by the
patient is a useful method of holding the resting leg in flexion whilst extension is being practised. Assistance to movement or graded resistance to muscle work can be applied by altering the fixation to assist or resist the movement and by applying spring or weight and pulley resistance.

*Hip abduction in prone lying.* As a progression if the patient is able to tolerate the position, abduction of both hips may be

![Combined and oblique movements of the leg](image)

Fig. 52. Combined and oblique movements of the leg.

practised in prone lying. Experience has shown that associated action of the hip extensors with the abductors is more pronounced in prone than in back lying, even though in both cases the legs are fully supported.

- **Combined and oblique movements.** Oblique movements combined with rotation can be obtained in the horizontal plane by turning the patient to the required position as indicated in Fig. 52. To suspend the leg for these movements two slings, one for the heel and the other for the thigh and two reciprocal pulley circuits are required. The leg rests in
Fig. 33. Flexion of the lower leg.

Fig. 34. Extension of the lower leg.

Fig. 35. Re-training for the quadriceps. Spring (A) supports the weight of the lower limb and spring (a) resists the contraction.
the slings and the ends of the pulley circuits are clipped to the ends of the slings. As the leg rotates it will roll freely in the slings and there will be no friction between the leg and the slings.

**Knee Treatments**

The patient will be in side lying with the leg to be treated uppermost. The foot and the lower leg will be suspended by axial fixation above the knee, and the thigh may either be suspended vertically above its centre of gravity or may be allowed to rest on a firm pillow. The latter method will stabilize the thigh more efficiently and is used if the range of knee movement is good and power is to be restored in weak muscles.

Graded resistances can be applied to the lower leg as the muscles gain power but if weights and pulley or springs are used some extra stabilization for the thigh may be necessary. If knee movement is limited and increased mobility is the main object of treatment, it is often more satisfactory to suspend the thigh as well as the lower leg and foot in order that a small range of hip movement can take place in association with the desired knee movement. If knee flexion is limited, the thigh should be suspended to a point anterior to its centre of gravity; in order that the hip may be held in flexion, the foot and lower leg will either be suspended by axial fixation above the knee or to a point posterior to the axis of movement (Fig. 53). If extension is the limited movement, then the position of the ropes will be reversed (Fig. 54).

**The Use of Springs as well as Suspension to Counterbalance the Action of Gravity**

Springs are frequently incorporated in the suspensory units when knee movements have to be re-educated. The following diagrams illustrate some of the techniques that have been found useful:

1. To re-educate control of the quadriceps (Fig. 55).
2. To stretch contracture on the posterior aspect of the knee (Fig. 56).
3. To train knee flexion (Fig. 57).
Fig. 56. Resisted extension of the knee used for stretching contractures of the posterior aspect of the knee joint.

Fig. 57. A method of increasing the range of knee flexion.
Walking in Suspension

If a patient is unable to bear full weight on one leg following a leg fracture, but the union is firm enough to stand some shearing strain, or if there is some muscle imbalance that is causing a limp, re-education of alternate weight transference can be practised in suspension against a graded resistance. The patient should be placed in lying, the upper part of the trunk and head being slightly raised by pillows. The pelvis and both legs are supported by vertical suspension, a small sling or foot strap is placed round both forefeet and is attached to springs in series with single ropes. The ropes are fixed to a point above the shoulders so that they form an angle of 5–10° with the front of the legs. A motion simulating walking can then be performed, one leg “down thrusting” as if taking weight and the other leg flexing as in preparation for the forward swing or the carry through in walking. The pressure of the strap on the forefoot will stimulate the plantar reflex and the more the down thrusting leg is extended the more the spring will be stretched and the greater will be the resistance to the working muscles. Since the pelvis is also
suspended the lateral tilt associated with weight transference will also take place. (Fig. 58.)

The calibre and tension of the springs must be equal on both sides as the main aim in using this technique is to teach the patient the “feel” of equal timing and equal thrust.
CHAPTER 10

The Application of Suspension for Movement in the Head and Trunk

*Spinal Movements*

When giving spinal movement in suspension, the part of the body that is resting or anchored on the couch should lie on a pillow or pillows, in order to bring it into line with the part suspended. When the legs and pelvis are suspended the hinged flap at the head end of the couch should be raised to prevent the whole body from sliding towards the axis of movement. If the hinged flap does not lock at an angle of about 30°, a folded blanket or hard pillow may be wedged.

![Diagram of trunk side flexion with axial fixation.](image)
between the frame and flap to keep it in position. A small pillow for the patient’s head is placed on the raised flap, and the patient’s shoulders should rest just below the line of the hinges (Figs. 59 and 60).

If the head and thorax are suspended, the feet should rest against a foot board or the wall (Fig. 61).

For Movement in the Lumbar Region

Suspension of the legs and pelvis is usually the most effective method to choose if movement is required in the lumbar spine. The pelvis is suspended from a line running across the body through the desired axis, but the ropes supporting the thighs and feet should be fixed as near as possible to the axial point. It is usually best to support the thighs in a single sling held by two ropes, but the feet may be supported separately or together. If side flexion is the required movement, the patient will be in lying with hips and knees slightly flexed, and when flexion and extension are to be performed the starting position will be side lying, hips and knees being either flexed or extended as required.

Fig. 60. Trunk flexion and extension with axial fixation.
Figs. 61 and 62. Two methods of supporting the patient and using axial fixation for trunk side flexion moving the head and thorax.
Technique for Relaxing Muscle Spasm in the Lumbar Region

This may be started with the patient in side lying, so that heat by irradiation can be applied for a short time before the movement is attempted. Breathing is then taught, encouraging the patient to perform posterior basal expansion on inspiration followed by abdominal contraction on expiration, which will help to gain reciprocal lengthening of the lumbar muscles. The physiotherapist stands behind the patient with one knee resting on the couch behind the thorax, which is steadied between one hand in front and the bent knee behind. The other hand, by exerting slight pressure on the back of the pelvis, encourages and assists movement in the lumbar spine. To gain flexion the movement is started by timing flexion of hips and knees with expiration and abdominal contractions, slowly progressing until the abdominal muscles are able to flex the lumbar spine a few degrees on each expiration without causing spasm of the lumbar muscles. The range is increased in easy stages, the effort being made on expiration; the physiotherapist holds the position gained by steadying the pelvis between each effort and allows the patient to pause and become used to the new position. When the fullest range of flexion has been achieved without causing further protective spasm in the lumbar region, the movement is slowly reversed. Now the effort will be on inspiration, but movement is still taken in easy stages until the fullest possible extension has been gained. During the transition of the legs from the position of extension to flexion, or flexion to extension, the length of the ropes suspending the feet must be adjusted. To roll the patient into lying the rope holding the upper foot and the rope passing from the back of the pelvis are lengthened, and if this manoeuvre is carried out skilfully, the patient can be helped to change his position smoothly and without discomfort. The slings and ropes are then adjusted and lateral flexion coaxed in the same way as before, i.e. the effort is made on inspiration and the range increased by easy stages.

Should it be desirable to start the treatment by giving lateral movement first, to turn the patient into side lying the ropes holding the side of the pelvis and the foot that will
become uppermost are shortened and, if necessary, those on the opposite side are lengthened.

**Technique for Mobilization**

If flexion is required, it is wise to shorten the ropes suspending the feet, and the patient is encouraged to flex hips, knees and spine more rapidly, timing the movement of flexion with expiration.

For extension the ropes supporting the feet are lengthened, and the effort is made on inspiration with hips and knees extended. If a full excursion from one extreme to the other is desired, the foot ropes may have to be shortened slightly. While these more rapid movements are being performed the patient may hold the top of the frame and the side of the couch to help to stabilize the upper part of the trunk.

**For Movement in the Thoracic Region**

If movement is to take place in the thoracic spine, the pelvis and legs will rest on the couch, supported by pillows if necessary, and the head and upper part of the trunk will be suspended on a line running across the body through the desired axis. The hooks supporting the head will be between those for the thorax and, if the arms are suspended, the hooks from which the arm slings are hung will be on the same line but outside the hooks supporting the thorax.

If lateral movement is required, the starting position will be lying, the arms may be suspended in a neutral position, or the patient may grasp the ropes supporting the thorax (Fig. 62). In some cases head or neck rest is a useful position for the arms, supported or unsupported, according to the condition being treated.

For flexion and extension in the thoracic spine the starting position will be side lying, and the arms may be folded across the chest inside the large sling or, if associated shoulder movement is desired, the arms are left free (Fig. 63).

It is sometimes more convenient to arrange the couch and slings so that the upper part of the body projects beyond the edge of the couch. To achieve this position a stool and pillows
may be used to support the head and thorax until they are suspended.

*Resisted Exercises*

With the patient in lying, springs incorporated in the suspensory units provide a useful means of obtaining resisted back extension. Here the rules governing the angle of resistance will apply, therefore if the range of extension is limited, the fixation points will be nearer to the feet than if the range of extension is free (Figs. 64 and 65).

In Fig. 65 for clarity the arms are not shown supported, but if strong work is required for the back muscles, the arms should be suspended at the elbows and the ropes, with springs incorporated in the unit, should be fixed in line with those for the head and thorax.

*For Movement in Head and Neck*

If movement is required in the cervical spine, the shoulders and the body rest on the couch and the head is suspended
Fig. 64.

Fig. 64 and 65. Resisted back extension in two ranges.
from points on a line running across the suprasternal notch. Rotation can be obtained if a rope running over two pulleys is used to support the head. The couch pillows and head sling are arranged, and as the patient lies down the head is guided into the sling (Fig. 66). This position is very useful for the treatment of spasm in the neck muscles, as heat and massage can easily be given to gain relaxation before movement is attempted.

Fig. 66. A head sling with pulleys to permit rotation.

Fig. 67. Resisted head extension.

Resisted work for the extensors of head, neck and upper thoracic spine can be given by incorporating springs in the suspensory units for the head sling (Fig. 67).

_Sacro-iliac Strain_

Opinions differ as to whether, other than during parturition, there is any real movement, as is generally understood by the term, in the sacro-iliac joint, and also whether sacro-iliac strain is in fact a clinical condition. Even if in normal circumstances movement between the articular surfaces is so limited that it can be written off as non-existent, it is possible that “stress” may cause a “strain” of the strong supporting liga-
ments that stabilize the joint. This may result in an inflammatory reaction that will lead to fibrosis. If this theory is accepted, it is then logical to argue that controlled movements, resulting in graduated and intermittent tension on these ligaments, will help to restore the normal “give” as opposed to “true elasticity” that exists in all healthy fibrous tissue. Experience has shown that in certain instances movement directed to the sacro-iliac region is beneficial in treating a condition in which the signs and symptoms point to a lesion in this joint. For example, in cases where extension of the leg or spine causes pain located to one or other sacro-iliac joint, suspension has been found to be of value, probably because sustained efforts to stretch the contracted structures can be obtained with very little associated muscle work and therefore less general fatigue. General mobilization as described for the lumbar spine with both legs and pelvis suspended can be practised, but to encourage a “stretch” on the sacro-iliac ligaments the suspension points should be over these joints and not over the lumbar spine.

In addition the following method has been found useful if localization of movement to one side is indicated. Supposing the left side requires special attention, then the patient lies on his right side with the right leg flexed at hip and knee, the leg being kept stable if necessary by a strap or bandage. To prevent forward movement of the trunk the patient may lean against the pillow and grasp the side of the couch. The left leg is suspended in slight abduction from a point posterior to the sacro-iliac joint and the patient is instructed to swing the leg into extension. The plane of this movement will be oblique and so will be more nearly parallel to the plane in which the ilium moves on the sacrum than is the case when the leg is suspended for pure hip extension.

The moving leg will therefore act as a lever and as it extends will assist in producing forward torsion of the ilium on the sacrum. In order to achieve movement in a plane that will fulfil these conditions it may be necessary to spend some time in adjusting the ropes until the most favourable starting position is obtained.
from points on a line running across the suprasternal notch. Rotation can be obtained if a rope running over two pulleys is used to support the head. The couch pillows and head sling are arranged, and as the patient lies down the head is guided into the sling (Fig. 66). This position is very useful for the treatment of spasm in the neck muscles, as heat and massage can easily be given to gain relaxation before movement is attempted.

Resisted work for the extensors of head, neck and upper thoracic spine can be given by incorporating springs in the suspensory units for the head sling (Fig. 67).

*Sacro-iliac Strain*

Opinions differ as to whether, other than during parturition, there is any real movement, as is generally understood by the term, in the sacro-iliac joint, and also whether sacro-iliac strain is in fact a clinical condition. Even if in normal circumstances movement between the articular surfaces is so limited that it can be written off as non-existent, it is possible that "stress" may cause a "strain" of the strong supporting liga-
The Use of Suspension in Teaching Relaxation

Vertical fixation will be used as the aim of treatment will be to give maximum comfortable support to the whole body. Total suspension is desirable if full relaxation is to be achieved. The technique as described in Chapter 6 should be used, and it will be found that the whole operation of lifting and adjusting the patient in the slings is simple and practical and the whole body will be under treatment. The patient is instructed to lie flat on his back and to “let go” his weight, so that every part of his body is borne by the sling supports on which he is lying. A floating sensation is felt; this is coupled with a complete confidence in the stability of the apparatus, which must be strong enough to support the heaviest patient. A sense of quietude steals over the patient and some degree of relaxation should be obtained even in a short time. The patient should preferably be screened off from others at this time and talked to in a soothing voice, or, better still, left quite alone to acquire the habit of lying still and achieving true repose. Some people are very difficult to influence and the inexperienced operator is apt to try to do too much, endeavouring to obtain relaxation and attempt mobilization of the joints or other complicated treatments all at the same time.

The great advantage of relaxation in suspension is that it is easy to learn and yet rapid in effect. This method has the advantage in that the floor (or support) is brought to the body instead of the body slowly giving up its weight to the support. When one lies down on a flat surface the prominent points of the body, such as heels, head, hips, shoulders, are in contact with the surface and it takes a long time for the rest of the
CHAPTER II

The Application of Suspension for Support

Suspension as a means of support is widely used in the nursing of patients where elevation of a part or dispersal of pressure is indicated. It is also used to enable severely paralysed patients to carry out functional activities which they would be incapable of achieving without this form of mobile support.

Short tension springs are frequently used to add buoyancy to the supporting unit. These springs are of heavy calibre, consequently the amount of extension possible without distortion is very small, therefore they must be of sufficient poundage to counterbalance the weight of the part without becoming distorted. In practice it will be found that heavy springs should be used to support the trunk, and generally medium springs are adequate for the head, arms and legs; however, with heavy patients, it may be necessary to support the thighs by using strong springs. The springs are usually incorporated in the suspensory unit between the hooks on the overhead frame and the ropes, so that the slight noise that is made by the springs as the patient moves, is far enough away not to irritate. If the springs are incorporated between the sling and the rope, this noise is nearer to the patient and can be extremely irritating, particularly if the suspension is being used to aid relaxation.

The physiotherapist will find many instances when suspension as a form of support will be valuable. In previous chapters the principles for the use of axial or vertical suspension have been emphasized, but rigid adherence to the exact rules will not always be desirable when using suspension primarily as a support. The aim of the treatment must be considered in relation to the condition of the patient as well as to the condition to be treated and the "means" adapted to suit
APPLICATION OF SUSPENSION FOR SUPPORT

Some patients find it easier to relax if “buoyant suspension” is used. This is achieved by incorporating short strong springs, between the hooks on the overhead support and the ropes that hold the slings.

**The Use of Suspension to Hold a Limb in Elevation**

Suspension is often a useful form of support when it is necessary to hold a limb in elevation so that gravity may assist venous and lymphatic drainage. Since weightless frictionless movements can take place in suspension, more activity with less fatigue is possible than if the limb is supported on pillows. In all cases the patient’s trunk should rest as flat as possible on the bed or couch with the head in a comfortable position on two or more pillows as required.

For oedema of the upper limb, if the range of shoulder movement is adequate, the arm should be vertical to the trunk, but for oedema of the lower limb the leg should be raised only to an angle of 45° to the pelvis with the knee in slight flexion.

![Fig. 68. The arm supported for treatment of oedema.](image)

Provided the hand is well protected by wool or felt a threering strap is generally used to hold the arm in position, but as a rule it is more satisfactory to wind a small sling round the foot and ankle if the leg requires this treatment. A greater range and variety of movement will be possible if a spring, strong enough to counterbalance the force of gravity, is incorporated in the suspensory unit.
body to let go in relaxation. It is also easy to adjust the slings to suit each individual and to obtain the exact degree of flexion that is most comfortable for each joint in the body.

The patient should have absolute confidence in his support, and the more comfortable the support the better. Care in the manner of handling patients and getting their trust and response cannot be too meticulous. The operator should direct his own and the patient's thought to quiet repose until a plastic state of mind is acquired. To assist this process deep expirations must be made; audible sighing expirations, if possible, as this will also assist the letting go process of the spine and chest wall. If the expirations are deep, the subsequent inspirations will also be deep. At the same time, as tension lessens in the chest, the spine will relax and be gently lowered to rest its length on the support. Breathing steadily relaxes tension and as the afferent stimuli from proprioceptors in muscles and tendons diminish, the patient may even drop off to sleep.

To test for relaxation. From time to time it is necessary to test a patient and find out how much relaxation he has achieved. Fortunately this is very easily and accurately done in the suspended state. A swing is started in any one limb, the operator stabilizing the adjacent part of the trunk and the number of oscillations of the swinging limb are counted before it comes to rest. In normal states the relaxed limb usually makes eight to ten oscillations. If the patient is tense or spastic, this swing is pulled up short, or there may be no oscillation at all. As treatment progresses, these tests will give a clear indication as to whether improvement is taking place or not.

Modifications. With deformed patients these conditions cannot always be fulfilled; for these subjects it will be necessary to find the best point of equilibrium by trial—care being taken to use large, soft slings, so that they will automatically adjust themselves to the contours of the body.

It has been found that sometimes a gradual introduction to this method of relaxation is best, as the patient's confidence must be won; thus, one can start by suspending the two arms then the two legs, and so on, till the whole body is under
APPLICATION OF SUSPENSION FOR SUPPORT 109

This order each ten times. For the leg: to move the hip, hip and knee, ankle, ankle and toes, in this order each ten times. All movements at each joint are practised in as full a range as possible. A short rest should follow each series of activities, the whole constituting one cycle of treatment. This cycle is repeated at regular intervals during the period for which the limb is in elevation.

By this means the proximal congestion is relieved and the drainage of the distal parts of the limb is facilitated. When the oedema has softened and decreased, the movements may be practised in the reverse order, thereby squeezing and pumping any residual distal pockets of tissue fluid towards the heart.

Suspension from a Mobile Point

BY D. F. TALBOT, M.C.S.I.P.

This technique has been developed at the Robert Jones and Agnes Hunt Orthopaedic Hospital as an aid to walking and crawling.

Apparatus

Use has been made of a gymnastic boom which is inverted so that the flat surface faces upwards. On this is mounted a roller skate connected to a wooden carriage (Plate VII). The two horizontal bars beneath the boom slip into sockets in the carriage, and thus make the apparatus easy to set up and remove. The horizontal bars provide four-point suspension by means of screw pulleys. Two short ropes are threaded through these pulleys ending in spring clips, from which four suspension ropes are attached. This arrangement has been found essential in order to allow for the lateral tilt of the pelvis in walking and to provide a downward pull when shortening the ropes with heavy patients.

The breeches which are applied to the patient in bed, or on a chair, are adjustable to a wide range of size and heights (Fig. 70 [w]).

The patient is connected to the suspension carriage whilst
This is a most effective form of treatment for the arm, but it is not always so useful for the leg for the following reasons:

1. The leg is heavier than the arm and therefore the supporting sling is more liable to cause constriction and impede drainage.
2. The vertical position is not comfortable for the leg.
3. Unless more than one support is used it is difficult to prevent hyperextension of the knee.
4. A support behind the knee to prevent hyperextension will tend to restrict drainage.

Routine of treatment. The following routine which is a useful preliminary to any other specific oedema treatment is readily adapted to a limb that has been suspended as described.

The patient is instructed to take ten deep breaths concentrating on expiration. Then for the arm: to move the shoulder, shoulder and elbow, wrist, wrist and fingers, in

Fig. 69. The leg supported for treatment of oedema.
still in a sitting position, and the ropes tightened. After this the bed or chair can be removed, and then the lengths of the ropes are finally adjusted to the patient’s needs.

**Techniques Used**

1. **As a means of restraint.** This is the most commonly used method and in this case the ropes are not tight when the patient is standing, nevertheless if the patient loses his balance, he can only sink down a matter of 4 in. (Plate VII). This technique is valuable combined with whatever walking aids the patient is using, until he is completely safe to walk without an assistant. In neurological conditions this sometimes takes hours of practice, and during this time it is unnecessary to have the physiotherapist at his side. He rapidly gains confidence, and he also learns the valuable lesson of regaining his own balance when he falls instead of being assisted back on to his feet. After the patient has walked the length of the boom he just relaxes back, and an assistant drags him backwards to the other end where he can begin again.

2. **To partially relieve weight from the legs.** In this case the ropes are taut. It is sometimes found necessary to apply some layers of cotton wool to the breeches to relieve uncomfortable pressure in the crutch. This technique is not so valuable, although in a few instances it can be used to train the pattern of walking, some time before the patient is fit to bear weight.

*Balance training.* By using either the breeches or the crawling sling (Fig. 70) and the ropes at a length offering restraint only, the Kabat stabilizing exercises can be usefully applied while the patient feels entirely confident about the safety of his position.
The harness for the breeches buoy. (a) Buttons and button-holes which fasten behind. (b) Buttons and button-holes which fasten in front. Duplication allows for adjustment to waist measurements. (c) Slots through which the waist-strap passes from the back. (d) Front suspension strap. (e) Back suspension strap. Duplication of rings allows for adjustment in height. The straps are stitched to the breeches only in their middle third, allowing for greater freedom of movement and adjustment.

> X, Y, Z. The harness for crawling.

(X) The trunk unit attached to the pelvic unit.
(Y) The pelvic unit. (A) Pelvic unit. (a) Trunk unit. (c) Shoulder supports. (s) Reinforced strip firmly stitched to the pelvic sling to receive the trunk band. (e) Trunk band, supplied with buttons and button-holes to allow for adjustment to the length of the trunk.
(Z) The support in position.
(A) Walking in the breeches buoy.

(B) The restraint to falling offered by the breeches buoy.
The Application of Springs and Pulleys for Resisted Movement

The exercises given in this chapter are intended to show some of the techniques and methods of setting up resistances to muscle groups throughout the body. In some cases the illustrations show resistance by springs only or by pulleys only, and other exercises show resistance by both methods. It has been shown that force opposed by a stretched spring varies with the extension; thus a spring is not suitable where an exercise or test call for resistance of fixed value. In such a case use should be made of the weight and pulley mechanism. The two mechanisms, spring and weight and pulley, are not altogether interchangeable.

1. When a spring is used the movements performed by the patient are usually of small range and the muscles therefore work chiefly in the inner ranges of their contraction. The spring extends with increasing resistance to the force applied to extend it, and as springs offer a variable resistance the output of force cannot be accurately measured. The patient has to perform a controlled return journey of the spring as it contracts or may be assisted on the return journey as the spring lifts the weight of the part.

2. Movements made against a pulley and weight resistance can be performed in full range. The weight lifted is of known fixed value and the patient performs the same work through the same range at each contraction. The work can be accurately assessed and a valuable test of progress obtained. The principle of effort and rest following each other in alternate rhythm is observed in all the following exercises, and they can be maintained for quite long periods.
Regional Exercises

1. The Trunk

The back extensors. For these muscles the alternative methods of pulley and weight or spring resistance may be used. Fig. 71 shows a resisted exercise in which the primary movement is in the back, and Fig. 72 shows a similar exercise which involves very little apparatus. Fig. 73 is a progression on the previous techniques as the base is smaller and the resistance may now be offered to both the hip extensors and the extensors of the back.

The abdominal muscles. Fig. 74 and Fig. 75 show resisted abdominal exercises in alternative positions. Approximately two 30-lb. springs will be needed for these exercises. This type of exercise cannot suitably be rigged for a weight
Finger exercises with a miniature apparatus.
the upright position during the exercise. The patient in Fig. 76B is in a slight stoop position working the anterior trunk rotators (oblique abdominal muscles) in their inner range.

**Trunk Side Flexors.** In Fig. 77 the patient is performing a resisted trunk side flexion in the inner range with a fairly fixed base.

![Fig. 77. Inner range trunk side flexion](image1)

![Fig. 78. Inner range trunk side flexion](image2)

![Fig. 79. Trunk side flexion with pelvic tilt](image3)

Fig. 77 shows the same muscle work and the exercise arranged where no overhead fixation is possible.

Fig. 79 shows a progression in which the trunk side flexors are working and lateral tilting of the pelvis is also possible.

**2. The Head**

Fig. 80 shows a method of applying resistance to the head and neck extensors.

**3. The Lower Limb**

The hip. Fig. 81 shows a combined exercise resisting extension of the hip and knee. This exercise could alternatively
and pulley, as the patient cannot then see the movement of the weight as the exercise is performed.

The Trunk Rotators. Figs. 76A and B show alternative methods of resisting trunk rotation. In Fig. 76A the posterior trunk rotators will work hardest and the patient maintains...
involves considerable control of the lumbar spine, or may be used to offer a resisted contraction to the extensors of the back in addition to the extensors of the leg.

Figs. 83A and B show a similar exercise for the abductors of the leg. Fig. 83A is the more difficult exercise and this can also be rigged against a pulley resistance. The exercise shown in Fig. 83B could be suitably rigged against spring resistance.

Fig. 84 illustrates resisted adduction and is a useful exercise where the patient has got generally weak muscles in the region of the hip, as the recoil of the spring will lift the leg into abduction when the abductors are too weak to do so. To prevent strain on the medial ligaments of the knee a spring unit can, if desirable, be attached just above the knee.

The knee. Fig. 85 shows the method of rigging the pulley and weight resistance for the extensors of the knee. If a spring is used for this exercise, then it should be fixed at one end in the position of the pulley A.
be set up with a weight and pulley apparatus, or bilateral exercise may be obtained by using either reciprocal pulleys or two spring units.

The patient in Fig. 82 is doing a short range leg extension, working the extensors in the inner range. This exercise

---

Fig. 80. Head and neck extension.

---

Fig. 81. Leg thrusting.
SPRINGS AND PULLEYS FOR RESISTED MOVEMENT

The foot and ankle. The exercises in Figs. 86, 87, 88 and 89 are designed to be carried out against the resistance of a

Fig. 85. Resistance for the knee extension.

Fig. 86. Dorsiflexion.

Fig. 87. Plantar flexion.

Fig. 88. Inversion.
Fig. 83. (A) and (B) Leg abduction.

Fig. 84. Leg adduction.
In Fig. 92 two alternative points of fixation are shown for offering resistance to outward rotation. It should be noted that if the patient has the ability to hold the arm in abduction then the sling may be removed in the later stages of treatment.

Figs. 93 and 94 show respectively forward and upward thrusting against spring resistance; and forward thrusting against the resistance of a pulley and weight. In the first case the patient may be required to perform either lateral rotation of the scapula only, or a combined extension of the elbow with a movement in the glenohumeral joint and lateral rotation of the scapula. The exercise performed against the weight and pulley resistance in sitting is more effective if it is used primarily to strengthen the forward thrust of the arm as opposed to the forward thrust of the scapula.

The apparatus illustrated in Plate VIII was designed by a student of the Swedish Institute in 1942 and shows a miniature spring suspension apparatus for re-educating finger movements.

Fig. 95 shows a position in which extension of the forearm may be resisted by a spring. This is used for treating patients in preparation for walking on crutches, when it is combined with the group of exercises at the end of this chapter. It is also of use when the triceps is weak.
helical spring rigged as a short spring unit. To plantar-flex the foot, the spring is attached to the head of the bed, or it may be held by the patient at the upper end by means of a handle. Only in resisted dorsiflexion is it necessary for the spring to be attached to some form of fixed point. In all cases the patient may be in long sitting or in lying, and the resisted inversion may also be suitably performed in sitting.

4. The Upper Limb

Fig. 90 and Fig. 91 show two methods of offering resistance to abduction of the arm, the first requiring a fixed point on the floor as the arc of movement is in the inner range of abduction. The arc of movement in Fig. 91 is through the full range of abduction of the arm.
Fig. 96 illustrates the resistance which may be offered to the abdominal muscles if the patient brings the spring handles together in midline of the body and with straight arms thrusts towards the feet at the same time as the head is raised.

Fig. 96. Arm thrusting and head raising in bed.

Fig. 97 shows the left arm in the rest position while the right arm performs a thrust at the side, and trunk side flexion is the resisted exercise in this case.

Similarly in Fig. 98 the arm is straightened obliquely.
Spring Resistance Exercises in Bed

Spring resistance exercises for patients who are confined to bed for long periods are illustrated in the following diagrams. They are designed to be performed with the simplest possible apparatus, and the majority of the exercises can be practised by small groups of patients. Each patient will require two units consisting of a rope, a spring and a handle; and one or two three-ring slings, depending on whether the patient is able to exercise only one or both legs. When a patient is confined to bed for a long period it is necessary to maintain the tone of the postural muscles and in many cases to train additional muscles such as the triceps, which will be required if the patient is to use crutches when first getting up.

Fig. 95 shows a simple resistance exercise for triceps.
across the body and the right shoulder is lifted from the bed to perform trunk rotation.

Fig. 99—If the fixed point of the spring is then lowered on the head of the bed and the arms are thrust down by the side as the back arches, resistance is offered strongly to latissimus dorsi and the extensors of the back, and the action of thrusting as in walking with crutches is performed.

Fig. 99. Back extension in bed.

Fig. 100. Flexion of hips with pelvic tilt in bed.

The exercise shown in Fig. 81 may also be adapted for use in bed, and the fixation point may be lowered to be attached to the head of the bed.

If the exercises illustrated in Fig. 99 and Fig. 81 are combined, then the complete thrusting action of crutch walking is obtained.

When the patient has weak abdominal muscles but is able to move both legs then the exercise illustrated in Fig. 100 will be of value. The patient lifts the legs against the resistance of the springs and contracts the abdominal muscles to round the lumbar spine.
CHAPTER 13

Orthopaedic Conditions

BY MISS J. A. HUGGAN, M.O.S.P., O.N.O.

Introduction

In this chapter an attempt has been made to describe some of the uses of suspension and allied techniques in the treatment of orthopaedic conditions. As this is an extremely large field offering much scope to the physiotherapist, the treatment of individual conditions has not been described, but treatments have been grouped where similarities exist.

Orthopaedic conditions fall into two main categories:

1. The Traumatic Field—In which healthy persons suddenly find themselves bedfast or severely limited in activity. One limb only may be affected but the period of immobilization or incapacity may be prolonged. Treatment in these cases has two purposes:

   (a) It is vitally important to maintain the muscle tone and power of the unaffected parts at maximum strength.

   (b) The injured part must be restored to normal function as soon as possible.

2. Non-Traumatic Field—This group can be subdivided into:

   (a) Patients suffering from flaccid paralysis caused by poliomyelitis or a lesion of specific nerves or nerve roots.

   (b) Patients entering hospital for major surgical procedure or for a period of rest and hospital care with the aim of improving the present state by either relieving pain or improving function.
Fig. 101. Resisted extension of the arm. (It should be noted that by using the bed head as the fixed point the angle of resistance is not necessarily ideal.)

Fig. 102. Foot exercises with strong fixator muscle work.

exercises. Fig. 101 shows the arrangement of the spring for resistance to the shoulder extensors, and it should be noted that by using the bed head as the fixed point the angle of resistance is not necessarily ideal. Where an overhead fixation is already provided on the bed, such as a Pearson pulley, this may be used to provide a better angle of resistance.

The exercise for the extensors of the elbow is shown in Fig. 95.

The neck and upper dorsal region. If there is an overhead fixation to which a spring can be attached, exercises for the neck and upper dorsal extensors can be given as illustrated in Figs. 64, 65 and 67. Alternatively the exercise shown in Fig. 99 may be used.

The hip and knee. A strong thrusting action is made with all the muscles of the leg (Fig. 81). The patient must pay attention, concentrate all the time and control the return movement, otherwise the spring will recoil and much of the value of the exercise will be lost. This thrusting exercise is
Physical Restoration showing the place of Suspension Therapy

Each of these groups may be treated using the same principles:

1. Maintenance
2. Restoration of
   (a) Confidence.
   (b) Full range of movement, power and function.
   (c) Full weight bearing when necessary.

The loss of power resulting from poliomyelitis or nerve lesions is dealt with later in this chapter.

First Principle

This should be the maintenance of function of the whole body, with the exclusion of the injured area, which will prevent deterioration by disuse.

The patient's posture in bed should be carefully watched and care taken to see that a good position is maintained, i.e. the head should be properly supported so that it does not poke forward, the weight should be evenly distributed on the buttocks with the spine in a normal position.

Function can be further maintained by:

**Free Exercise Ward Classes** given preferably to music. This encourages and interests the patients and even the elderly are willing to join in.

**Spring Resistance Exercises.** These can be carried out in a class or individually under supervision once a day; selected cases may practise at intervals throughout the day if the springs are left with them.

The apparatus required for such exercises is described in Chapter 12 and the following regions should be exercised:

The arm. The extensors of the shoulder and elbow, which are used by the patient for lifting himself in bed and later for the thrust action of walking with crutches. These two actions are not normally used and it is therefore necessary to build up additional power in the extensor muscles. Such power is readily built up by means of repetitive resistance
be done by active assisted and active exercises carefully graded and adapted to fit each case. Suspension therapy is of great use in restoring movement to a stiff joint, as by supporting the part to be mobilized the action of gravity is counterbalanced and the weakened muscles can therefore produce movement without having to contend with the weight of the limb. Suspension (by the nature of its support) also induces relaxation in the muscles surrounding the joint.

Movement may be performed as follows:

1. The physiotherapist may initiate the movement and so enable the patient to regain "the feeling" of activity.
2. The patient may perform small range repetitive movements which will help to reduce muscle tension and give the patient confidence in his ability to control the limb.
3. The patient carries the limb to the limit of painfree movements—holds statically—and then attempts to increase the range.

**Lower Limb**

The hip. It is necessary to mobilize the hip for a number of conditions:

(a) Following arthroplasty by insertion of either a Smith Petersen type cup or a Judet acrylic prosthesis.
(b) In the later stage of a fractured neck of femur which has been pinned, or pinned and plated.
(c) Dislocation of hip (late stage).
(d) Arthritis in patients in hospital for conservative treatment.

(a) Following arthroplasty of hip either by Smith Petersen cup or acrylic prosthesis. After this operation the patient is nursed on Hamilton Russell traction with a weight of about 7 lb. The leg is sometimes fixed in internal rotation either by pin fixation through the tibia or by a rotation bandage. Static quadriceps, and gluteal contractions and foot and ankle movements together with breathing exercises are given.
of great importance and will use all the leg muscles as in walking, the pressure of the sling will stimulate sensory impulses in the sole of the foot, and thus additional proprioceptive impulses will facilitate muscle contraction.

Abduction and adduction of the leg may also be practised if the patient holds the spring unit to the side at the level of the leg, laterally for the adductors and medially across the body for the abductors.

The foot. The thigh and leg are raised so that they are at right angles to each other and to the bed. The forefoot is supported by a three-ring sling to which is attached a suitable spring. The other end of the spring may be attached to the bed head or may be held by the patient by means of a handle. This rather insecure position makes the foot muscles work hard to grip the sling and when the spring is put on tension the leg muscles will also work as additional fixators.

The patient is now instructed to manipulate the handle and spring or the rope in order to obtain resistance successively to the plantar flexors, the invertors and evertors of the foot (Fig. 102).

The trunk. Figs. 96, 97 and 98 illustrate suitable exercises for the rotators and side flexors of the trunk; and for the abdominal muscles.

With a single fixation point only above and behind the patient the exercises are largely limited to thrusting movements. However, these activities are some of the most valuable for toning up the anti-gravity muscles of leg and back. The muscle work is concentric when the spring is elongated and eccentric when the recoil of the spring is controlled by the patient.

**Second Principle**

1. **Restoration of function.** The physiotherapist must first gain the confidence of the patient and explain how important a part he plays in his own recovery programme. It is only with the patient’s full co-operation that the best results are obtained.

2. **Restoration of movement.** After the removal of any fixation the first aim is to mobilize the stiff joints. This can
(At least 5 minutes in every hour.) The quadriceps will always waste if the leg is immobilized for any length of time, and the sooner physiotherapy is started the better.

**Some of the Conditions which commonly cause stiffness of the knee:**

1. Fractures of the femur particularly of the lower one-third and supracondylar fractures.
2. Fractures of the tibial plateau and tibial condyles.
3. Following operations for Patelllectomy, Synovectectomy, Menisectectomy, Rupture of medial ligament.
4. Dislocation and traumatic effusion of the knee.

The time at which movement may be started varies with the condition, the speed of recovery and X-ray findings. In fractures of the femur some surgeons use a Pearson flexion piece fitted to the Thomas's splint which allows for early movement while the leg is still on traction. If fixed traction is used, knee movements are delayed until it is removed at approximately 3 to 4 months.

The immediate treatment consists of teaching static quadriceps and gluteal contractions, emphasis being placed on the former. As soon as possible the patient should be required to do straight leg raising in the support, whether it is plaster of Paris, a back splint or a pressure bandage. Foot and ankle movements are also given.

Mobilization may be started at the following times:

- **Patellectomy** . . 3 weeks after operation, but after 2 weeks in cases where the quadriceps expansion is intact at operation.
- **Synovectomy** . . After 2 weeks or, in the case of a tuberculous infection, not for 3 weeks.
- **Menisectectomy** . . After 10-12 days.
- **Dislocation of knee** . . After removal of the plaster at about 8-10 weeks.

The knee can now be mobilized (see Chapter 9).
Care must be taken to see the patient lies flat for at least an hour twice a day and throughout the night to prevent flexion deformity of the hip. The time at which to start abduction and flexion varies from the third to the tenth day. Bilateral movement can be started at twelve to fourteen days following the removal of the sutures. The Russell traction is removed for treatment and replaced afterwards. Suspension may be used as an alternative to the skate and board, provided no harm may result from consequent rotation at the hip. Later, when the patient is no longer confined to bed, suspension is a most valuable means of restoring hip movement. The traction is usually removed 4 weeks after the operation.

(b) Fractured neck of femur. Hip movements are usually restored by encouraging movements of the trunk. If stiffness of the knee persists, suspension therapy may be of value. Abduction and adduction are not performed for 3 months as these movements place too much strain on the pin.

(c) Dislocation of hip. These patients are nursed on Hamilton Russell traction. Providing there is no nerve involvement, gentle flexion and extension may be started at 3 weeks, traction being removed for treatment. If the patient has difficulty in regaining hip and knee movements, suspension therapy may then be of value.

(d) Arthritis of the hip. These cases are usually unsuitable for operative treatment. They often have an adduction-flexion contracture and the suspension technique must be adapted to increase extension and abduction at the hip joint.

When giving treatment for the hip the patient will be in lying for abduction and adduction and it may be more satisfactory if the movement is bilateral to prevent pelvic movement. If this is impractical, care should be taken to fix the pelvis by placing the patient's good leg over the side of the plinth (Fig. 28). For flexion and extension the patient will be in side lying (Fig. 27).

The knee. This is one of the most difficult joints in which to restore full function. The importance of early movement cannot be stressed too strongly. Movement must be active and must be practised constantly throughout the day.
(At least 5 minutes in every hour.) The quadriceps will always waste if the leg is immobilized for any length of time, and the sooner physiotherapy is started the better.

Some of the conditions which commonly cause stiffness of the knee:

1. Fractures of the femur particularly of the lower one-third and supracondylar fractures.
2. Fractures of the tibial plateau and tibial condyles.
3. Following operations for Patellectomy, Synovectomy, Meniscectomy, Rupture of medial ligament.
4. Dislocation and traumatic effusion of the knee.

The time at which movement may be started varies with the condition, the speed of recovery and X-ray findings. In fractures of the femur some surgeons use a Pearson flexion piece fitted to the Thomas's splint which allows for early movement while the leg is still on traction. If fixed traction is used, knee movements are delayed until it is removed at approximately 3 to 4 months.

The immediate treatment consists of teaching static quadriceps and gluteal contractions, emphasis being placed on the former. As soon as possible the patient should be required to do straight leg raising in the support, whether it is plaster of Paris, a back splint or a pressure bandage. Foot and ankle movements are also given.

Mobilization may be started at the following times:

Patellectomy . . 3 weeks after operation, but after 2 weeks in cases where the quadriceps expansion is intact at operation.

Synovectomy . . After 2 weeks or, in the case of a tuberculous infection, not for 3 weeks.

Meniscectomy . . After 10-12 days.

Dislocation of knee . After removal of the plaster at about 8-10 weeks.

The knee can now be mobilized (see Chapter 9).
1. In side lying with the leg to be mobilized uppermost, the foot and lower leg are suspended by axial fixation above the knee and the thigh either suspended vertically above its centre of gravity or supported on a firm pillow.

One movement should be re-educated at a time. The patient is first asked to straighten the knee by stretching the foot and lower leg forwards, holding the position and then relaxing. When this has been mastered, manual resistance may be applied in front of the ankle. To give eccentric work for the quadriceps, the physiotherapist asks the patient to resist slightly as she bends the knee against the patient’s resistance.

Having exercised the quadriceps, it is then necessary to exercise the hamstrings. The physiotherapist straightens the leg and then asks the patient to bend his knee, this is repeated several times. To progress the exercise manual resistance may be supplied at the back of the heel and the patient again asked to bend his leg. Eccentric muscle work for the hamstrings may then be given by the physiotherapist straightening the knee against the patient’s resistance.

2. By moving the fixation point to axial over the hip and fully suspending the leg a combined hip and knee movement as in cycling may be performed.

3. Spring resistance exercise for the quadriceps in inner range; as shown in Fig. 56. The patient is asked to press the knee on to the bed and to relax slowly so resisting the recoil of the spring and working the quadriceps eccentrically.

**Upper Limb**

**Shoulder joint.** This joint is frequently injured by old people and early treatment is essential in order to obtain good functional recovery. Great care is needed to isolate true shoulder movement (humeroscapular) as it is very easy to get trick movement by moving the whole shoulder girdle.

**Conditions:**

- Dislocation of shoulder (later stages).
- Fracture of greater tuberosity of humerus.
- Fracture of neck of humerus—Impacted or non-impacted.
- Supraspinatus strains.
- Peri-arthritis—frozen shoulder.
The time at which mobilization starts varies with the different injuries, but treatment follows the same pattern.

The aims are:

1. To relieve pain and muscle spasm.
2. To obtain relaxation.
3. To restore full range of joint movements as soon as possible.

The patient should be treated in the recumbent or semi-recumbent position. Radiant heat and sedative massage may be given to relax the protective muscle spasm. As soon as repetitive movements are possible exercises in suspension may be given. The arm should be suspended with axial fixation over the shoulder joint. The physiotherapist must fix the scapula to prevent movement in the shoulder girdle. The patient is asked to swing the arm out gently to and fro, and then the halt and distance tests may be employed.

Elbow joint. This joint is one of the most difficult to mobilize and must never be moved passively. Isolated repetitive movements are not usually desirable following:

Dislocation;
Fracture of the head of the radius, and of the olecranon process;
unless the two latter are treated by excision.

Suspension is of value following arthroplasty of the elbow or in the later stages following injury when there is no danger of causing myositis ossificans. By supporting the arm in suspension, with the patient in sitting it is possible to mobilize the joint by gentle movements. This induces active contraction with relaxation of the opposing muscle group (Figs. 49A and B).

Spine. Suspension is useful for the following conditions:

1. Crush fracture of body of vertebrae before and after removal of the plaster jacket.
2. Fractures of transverse processes of vertebrae as soon as possible.
3. Low back pain due to bad posture and muscle strain.
Mobilization of the lumbar spine is most successfully carried out by suspending the pelvis and legs. The techniques advocated are those described and illustrated in Chapter 10.

**Poliomyelitis and Peripheral Nerve Lesions**

A patient suffering from an extensive flaccid paralysis contends with great difficulties on attempting movement, until the muscles have sufficient power to move the part against the resistance of gravity. Therefore at this stage suspension constitutes a useful means of treatment, especially before pool therapy is possible. While the two media are similar in counterbalancing gravity and constitute an easy means of moving, pool therapy does not allow the isolation of muscle groups possible in suspension. A patient can easily be kept warm during treatment in the pool but general exhaustion soon arises, whereas in suspension different parts of the body can be exercised in turn and the patient’s effort directed towards specific efforts for longer periods. Since the programme of re-education must be continuous throughout the day and frequently has to be prolonged over weeks or months, suspension offers a valuable alternative to other forms of re-education. It is particularly valuable as a means of obtaining the localized repetitive movements that are essential to regain muscle power. The physiological and mechanical factors that oppose movement, the techniques of suspension, and the application of graded resistances are described in Part i of this book.

In the treatment of poliomyelitis suspension cannot suitably be used in the acute phase when only passive movements and positioning of the patient are possible. When the temperature subsides and the patient may attempt active movement, suspension is of value:

1. To assess voluntary movement.
2. To obtain full range of movement as the patient will often relax against the lesser pressure of slings if tenderness is still present.
3. To obtain repetitive maximal contraction of muscles
and muscle groups which the physiotherapist is free to resist, control and palpate.

4. In conjunction with graded weights or springs to build up muscle power.

If the patient is still complaining of tenderness in his limbs, the slings may be padded with sorbo rubber.

To assess voluntary movement. It is usual to classify muscle strength by finding out if a muscle can work against gravity and then to see how much resistance can be offered. When a muscle is classed as 1—unable to withstand the force of gravity—other available tests can detect a “twitch”, but with the aid of the suspension apparatus it is possible to use the Oscillatory, Distance and “Halt” tests described in Chapter 6 for assessing the sub-gravity state. The techniques used for the Distance and Halt tests form part of the treatment programme.

When the muscle or muscle group is classified as 2 (movement with gravity neutral) progress towards 3 can be graduated by resistances applied to the limb. The suspension should be axial and the resistance is supplied by attaching a spring or a weight and pulley circuit. Obviously the weight used at this stage must not exceed the weight of the limb.

To examine the trunk. With the patient’s two legs in suspension it is possible to get a general picture of the extent of bilateral movement, any asymmetry in leg movements being easily discernible. When the patient lies with the head and thorax on the bed and the pelvis and legs suspended, the lower abdominal muscles can be tested. By lowering the pelvis and legs and supporting the head and thorax, it is possible to test the upper trunk muscles and those moving the head and neck. Side lying is used to test rectus abdominis as a trunk flexor, the back and neck extensors and the flexors of the head.

Lying is used to test the side flexors of the neck and the trunk, especially trapezius (upper fibres), latissimus dorsi, quadratus lumborum and the oblique and transverse abdominal muscles. In the case of quadratus lumborum the disparity of levels of the bony prominences of the pelvis is
often observed as soon as the pelvis and legs are suspended. To examine the limbs, axial fixation is used over each joint in turn and the three tests named above are employed.

**General Points to be Observed**

1. The limb is first suspended axially and a full-range passive movement carried out.

2. When muscle power is nil or minimal, movement is initially assisted by the physiotherapist, and the patient makes an effort to continue; the limb is then carried back by the physiotherapist.

3. As strength increases slightly the patient can be encouraged to perform a to-and-fro swinging movement which will give them "the feel" of the movement.

4. Very soon the patient, with the limb still suspended axially, is asked to perform a "one way" movement, gradually increasing the range, and then the ability to halt and hold is trained. The physiotherapist returns the limb to the neutral position each time.

5. The fixation is then varied from axial to offer the resistance of gravity to specific muscles or muscle groups, the patient attempts to carry the limb up and out, and first the physiotherapist carries the limb back to neutral, later the patient is asked to control the return journey.

6. Manual and mechanical resistances are used as power returns.

7. At all times the patient must be carefully watched and prevented from performing "trick movements".

**Treatment**

L.E.O. When using suspension for the treatment of a patient with a flail leg, particular care must be taken not to stretch the ligaments of the knee. Therefore whether the patient is in lying or side lying, the thigh should be adequately supported.

**Leg abductors and adductors.** The patient must lie on his back with the whole leg supported at the knee and foot and the fixation point axially above the hip joint. The physio-
The therapist must check carefully that movement occurs at the hip joint and that the patient does not "cheat" by using his trunk side flexors instead of the abductors: or that he does not adduct his leg and then relax so that the limb swings back. The patient is asked to perform the movement of abduction and adduction or may be asked to concentrate on one movement or the other. If there is unequal muscle balance—which is very often the case, i.e. one group is very much stronger than its opposing group, it is necessary to treat each group separately. For example, if the abductor group is being treated, the point of suspension must be altered so that some resistance is offered by gravity to abduction, that is, it is placed medially towards the other leg. The patient then performs one movement—abduction, the limb is carried back by the physiotherapist and the movement repeated. As the muscle strength increases, resistance may be increased either manually or by use of springs or weight and pulley. Manual resistance is offered on the side working, i.e. in the direction of movement, first on the thigh and then the ankle.

**Hip flexors and extensors.** The treatment is carried out as for abduction. If the quadriceps are not strong enough to maintain the knee in extension, a short, light back splint can be applied to support it.

**Quadriceps and knee movements.** The extensors are the most important group to re-educate. To facilitate the re-education of the quadriceps within the general extensor pattern of the leg, the thigh should be supported so that the hip is held in extension (Fig. 54). The lower leg is suspended with axial fixation over the knee, which may be modified to assist or resist as necessary.

The movement is initiated by the physiotherapist and then the patient is encouraged to "kick out". By moving the thigh fixation so that the hip is now flexed the hamstrings can be trained in a similar way (Fig. 53). Eventually a combined hip and knee flexion and extension can be practised, and later graded resistances are added to all actions.

**The upper arm.** The deltoit is one of the most common muscles requiring re-education in the upper limb and it is very important to isolate the movement of abduction. The
operator must not leave the patient and care must be taken to see that he does not "cheat" by hunching his shoulder using trapezius. The exercise can be resisted as the muscle power increases.

The elbow. In other parts of this book, little has been said about the modifications of suspension techniques for conditions affecting the elbow since this treatment is unsuitable in most cases. However, in the treatment of a patient who is suffering from the after-effects of paralysis, particularly affecting the flexors of the forearm, suspension can offer a very valuable medium of treatment. The repetitive movements necessary to build up muscle endurance are easily carried out when the arm is suspended.

If possible, the patient should be in the upright position with the trunk fully supported at the back. This position can be used for short periods even if the trunk muscles are affected. The technique is modified to enable the patient to concentrate on the functional movement of bringing the hand to the mouth. The upper arm is suspended from its centre of gravity with the fixation point towards midline and anterior to the body, in order to hold the arm in sufficient flexion. The forearm is supported in a single sling attached to either end of a reciprocal pulley circuit; the axial fixation is modified to assist or resist as necessary. In this position the patient can practise isolated repetitive movements and may carry out functional activities such as feeding, washing, etc. In order further to build up muscle power, graded resistances can be applied to the forearm.

In the treatment of patients suffering from orthopaedic conditions and peripheral nerve lesions it is probably true to say that accuracy is more important than in any other field of physiotherapy. The physiotherapist's own technique in arranging the apparatus must be good, the patient must be carefully taught and supervised so that he is aware of the immediate and ultimate aims of treatment. By observing these points and giving constant encouragement the patient can be directed towards increased self-reliance and activity.
CHAPTER 14

Suspension Exercises in the Treatment of Cases coming under the Heading of the Rheumatic Diseases

BY W. YEOMAN, M.D.
AND MISS B. SAVAGE, M.SC., M.O.S.P.

The aim of all treatment of cases coming under the above heading is the restoration of function in the locomotor system, and generally speaking this is best achieved by exercises in water, but where such facilities are not available suspension exercises are a good substitute. By this means the force of gravity is overcome and by the judicious arrangement of the slings and springs, weakened muscles can be assisted and muscle spasm due to pain averted.

Before going into details of the exercises to be performed with the aid of suspension, it is necessary to have an understanding of the underlying condition which is causing the limitation of function. In contrast to patients who have loss of function due to trauma, and except for the loss of function are well in general health, patients in this group are frequently suffering from a general disease the cause of which is at present unknown.

For practical purposes the cases can be divided into three groups:

1. **Non-articular**—in which muscles, fibrous tissue, tendons and joint capsules are affected.
2. **Rheumatoid arthritis**—which may start in the peri-articular tissues and end in gross joint destruction.
3. **Osteo-arthritis**—which may start in one joint and remain non-articular but more frequently affects many joints, particularly of the weight-bearing type.

Cases coming under the first heading rarely require
assisted exercises, with the exception of the stiff shoulder joint which may progress to the classical "frozen shoulder" of American literature. Whatever the cause for the limitation of movement at this joint, X-ray evidence of cartilage destruction or developing arthritis is rarely to be found. Nevertheless, marked reduction in the range of movement, particularly abduction and internal rotation, is an irritation to the patient and restricts the performance of ordinary personal routine duties. It has been found by experience that the forceful methods of treatment frequently make the condition worse and retard complete restoration of movement. If the joint has to be manipulated under anaesthesia, voluntary assisted exercises should be instituted within 48 hours of the manipulation and continued daily until the acute phase has passed and restoration of function is almost complete.

In the milder cases after treatment designed to produce localized hyperaemia of the peri-articular tissues, assisted exercises graduated to increase the range of movement each day will be most helpful.

The other type of case coming under this heading is postural kyphosis and scoliosis occurring in young people before bony changes have occurred. By means of full or partial suspension self-correction of the deformity is produced and weakened back muscles are exercised.

The patient with rheumatoid disease is in a different category from all others to be treated by assisted exercises. Here the patient is suffering from a disease affecting the whole body and requires treatment when the disease is still in an active phase. The joint to be exercised in addition to showing the results of chronic inflammation, e.g., destruction of cartilage and erosion of bone, is surrounded by synovial membranes and ligaments which have already suffered in the early stages of the disease. The muscles concerned with joint movement have become weakened both from disease and from changes in the muscle fibres and collagenous material, due to the disease itself. The patient, because of pain, has increasingly restricted joint movement and in consequence morale is at a low ebb.

The initial stage of the treatment of this disease is rest in
bed, but when the physician has decided the time has come to move the joint actively, the suspension exercises are the first to be instituted. No attempt should be made to force movement but the slings, pulleys and springs can be so adjusted as to enable the patient to move a joint through a greater range of movement than was possible when the limb was not supported. Progress is naturally slow and the length of time allowed for each exercise session must be limited so that fatigue is not produced and pain and inflammation in the joint not increased. An increase in the range of movement of a joint, however slight, is of great encouragement to the patient.

In the later stages of the disease when contractures have occurred it may be decided to correct the contractures either by graduated splinting or manipulation under anaesthesia, followed by encasing the limb in plaster. When the plaster cast has been bivalved and voluntary exercises are permitted the assisted exercises given in suspension are the first to be introduced. However, it must be remembered that a joint so manipulated is in a potentially active phase, and the same care as to length of exercise session, strength of spring resistance and range of permitted movement must be controlled as carefully as if the joint were in the initial phase of the disease.

In recent years intra-articular injections of either a local anaesthetic, e.g. procaine or one of the hormone derivatives, e.g. hydrocortisone, have been given before exercises are started. When this is the case extra care is required because these injections, in view of their anaesthetic effect, enable a joint to be moved through a greater range of movement before pain is produced. Thus both the patient and operator may be encouraged to give the joint more movement than is wise and in consequence there is an increase of inflammation when the anaesthetic effect has worn off. This warning is also necessary where patients are taking one of the hormone derivatives systematically.

A disease process related to rheumatoid arthritis but differing from it in many aspects is ankylosing spondylitis. This condition affecting chiefly young males, starts usually
SUSPENSION THERAPY

in the sacro-illiac joints and gradually affects the whole spine. One of the earlier areas to be affected is the dorsal vertebral area, and this causes considerable limitation of the rib movements with consequent reduction in vital capacity. The modern treatment is for the sacro-illiac joints to be treated by exposure to deep X-ray and afterwards to encourage spinal exercises, particularly chest expansion. By means of suspension, as advised in the treatment of postural deformities, exercises for strengthening the back muscles and also increasing respiratory excursion can be instituted. By these means an attempt is made to minimize the distressing kyphosis which so frequently occurs as the disease progresses.

The illustrations in Chapter 10 show suitable exercises which may be used for this condition. It is usual to start with those shown in Figs. 67, 64 and 65, in that order, and progress to the mobility exercises shown in Figs. 63 to 59.

In view of the universal increase in expectation of life the group of osteo-arthritis cases is bound to increase, and already absorbs the majority of the time of physiotherapists working in the out-patient departments. This is a degenerative joint disease commonly affecting the weight-bearing joints and though many theories have been advanced for its cause, the prevalent opinion is that it is due to repeated trauma, often imperceptible, but repeated over a prolonged period. The disease is characterized by proliferation of bone at the margins of the joints with destruction of cartilage resulting in limitation of movement and considerable pain. The pain is considered to be due to changes in the capsule of the joints and spasm of the adjoining muscles and affects chiefly the knees, hips and lumbar spine. The disease may affect only one joint, e.g. hip, but more frequently in course of time other joints become affected as the patient alters the stance or gait to avoid causing pain. The onset is insidious, but acute episodes occur and it may be one of these which decides the patient to seek medical advice. Then when the joint is X-rayed it is seen that the condition has been present for a considerably longer time than the patient realizes.

Heat which can penetrate to the capsule of the joint gives temporary relief and after such treatment suspension exerci-
EXERCISES AND RHEUMATIC DISEASES

Because the capsule and peri-articular tissues are affected and tend to contract, suspension should be arranged so that the limb is stretched and "trick" movements prevented (Figs. 55 and 56). As the joint changes are chronic in character, treatment can be more strenuous and the spring resistance stronger than was the case with the rheumatoid joint. The aim should be to obtain the maximum movement at the joint with each excursion of the swing or pulley movement. In the case of the knee joint the earliest group of muscles to be affected is the quadriceps and there is a rapid wasting and loss of power in this group. The object of all such exercises is to improve the strength of these muscles because their weakness causes a feeling of insecurity. This sensation, felt more particularly on going downhill or downstairs, frequently precipitates a fall. Figs. 53 and 54 to mobilize the knee, and Figs. 56 and 81 to strengthen the quadriceps.

Osteo-arthritis of the hip joint is greatly helped by frequent courses of assisted exercises in all stages of the condition. Recent research seems to indicate that in the hip joint the areas which do not bear the full weight initiate the degenerative reaction which gradually involves the whole joint. This would seem to indicate that the reduction of movement in the first instance starts a vicious circle which only ceases when the joint becomes ankylosed.

This joint for many years has been the subject of varied orthopaedic operations and it is important for the patient to have a course of exercises before an operation. This improves the strength of the muscles and also shows the patient what is expected of him after the operation. While the patient is still in bed after the operation suspension exercises will assist in building up the muscles controlling joint movement, and should be given daily in increasing length of time and range of movement during the whole of the convalescence. Figs. 27 and 28 and those in Chapter 12. Some cases where operation is not indicated or desired can be kept active and reasonably comfortable for many years by having regular courses of these exercises.

This brief summary of the value of assisted exercises in the
treatment of the rheumatic group of diseases emphasizes the value of re-education of movement in diseased joints. The aim of the physiotherapist and the patient should be to improve the muscle tone that the movements can be performed without the assistance of suspension. The wider range of joint movement in itself is important in that it helps to make the patient independent, but even more than this is the increase in morale which such objective improvement engenders.
CHAPTER 15

Physiotherapy in Spinal Paraplegia

BY L. OUTTMANN, O.B.E., O.St.J., M.R., M.R.C.P.,
AND MISS H. T. BELL, M.C.S.P.

Introduction

Any severe lesion of the spinal cord always presents a disability of great magnitude. The paralysis which inevitably follows a spinal cord lesion involves such essential functions as motor, sensory, vasomotor, bladder, intestinal and sexual functions. Recollections of treatment of paraplegic patients in the past leave depressing memories of hopelessness and helplessness. One remembers apathetic men and women with sallow complexions: patients emaciated from septic absorption from foul-smelling pressure sores and urinary infection. The expectation of life for these unfortunate sufferers was generally assessed at not more than two years. Those patients who managed to survive were doomed to spend their lives as useless and unemployable cripples—professional charity cases in institutions or at home—with poor consolation of perhaps a little basket-work as the only hope for the future. It is, therefore, not surprising that the subject of paraplegia has hardly been mentioned in publications on rehabilitation during former years. However, experience during recent years has shown indubitably that such cases, if treated properly from the beginning, are by no means hopeless. In fact, the modern principles of rehabilitation can be applied to most of these patients, to restore their will to live, in spite of great physical handicap, and win their hearts and minds back to activity and useful work, so that they can once again take their rightful places in social life. Since it has been realized more and more that everyone connected with the rehabilitation of a paraplegic is confronted in all stages of his work with the task of rescuing not only a
broken body but also a broken personality, definite progress has been made in the solving of a problem, hitherto considered as one of the most depressing in medicine.

The first step forward in the systematic study of the whole problem in Great Britain was the setting up of spinal units during World War II. One of these was the spinal unit at the former Ministry of Pensions Hospital, Stoke Mandeville, which started from scratch in February, 1944, but developed later into the largest unit of its kind in the British Commonwealth and Europe and has for some years been a national institution, receiving patients from all over the British Isles. It consists of six male and two female wards (with a small annexe for paraplegic children), with altogether 175 occupied beds, and deals with both service and civilian paraplegics. Associated with this centre are convalescent units and hostels in London and Eastbourne and a spinal unit at Cardiff. The principles and methods of treatment and rehabilitation of paraplegics, developed in this Centre, have been widely accepted all over the world and have served as a guide to other hospitals and units concerned with the rehabilitation of paraplegic patients. Regular post-graduate courses for nurses and physiotherapists are held, in which students from the British Commonwealth and other countries take part.

This chapter is concerned with the physical restoration of paraplegic patients. Although it deals mainly with traumatic paraplegics, the general principles can, of course, be applied to paraplegics of any cause—whether poliomyelitis, transverse myelitis, tumour, congenital abnormality such as spina bifida, or vascular processes.

Since the inception of this Centre, over 1,700 paraplegics have been treated, the majority of them (over 70 per cent.) traumatic. The mortality rate in this Centre is about 8 per cent., which includes not only everyone who died in Stoke Mandeville Hospital but also those who died after discharge home or to other institutions; it also includes paraplegics who died from causes other than the usual sequelae of a spinal cord lesion (sepsis from bedsores or urinary infection).
Considering the present very low mortality rate of paraplegics, as compared with the extremely high one (80 per cent.) in the First World War and after-war period, it is quite clear that, today, the problem of paraplegia is no longer only a medical one but also a social one of increasing importance. It is, therefore, obvious that everyone concerned with the treatment and rehabilitation of paraplegics must work towards restoring the patient to be a useful member of society. This has been achieved not only with paraplegics with distal spinal cord injuries but also with those with higher lesions and, today, more than 70 per cent. of the well over one thousand paraplegics discharged from Stoke Mandeville are gainfully employed.

In the team work of adjusting even such severely disabled persons as paraplegics to their permanent disability, so that they can once again take their rightful place in society, the physiotherapist plays a very important part. For, today, it is no longer a question of whether a paraplegic can be restored to a useful life but how soon, and the concentrated efforts of the physiotherapist can help to speed up the rehabilitation of these patients.

Since 1944 the principles and techniques of physiotherapy in paraplegia, as developed in this Centre, have been repeatedly published elsewhere (Guttmann, 1945, 1946, 1949, 1951, 1954; Bell, 1954; Hobson, 1956).

Principles and Objects of General Treatment
The rehabilitation of paraplegics is a very complex process and includes a long series of activities, which fall into four main categories:

1. First aid.
2. Initial and early treatment.
3. Physical and psychological readjustment.
4. Domestic and industrial resettlement.

The patients are transferred to this Centre at various intervals after injury and in varying conditions from first aid posts, base hospitals, general hospitals and other medical institutions, or from home. One group is admitted
broken body but also a broken personality, definite progress has been made in the solving of a problem, hitherto considered as one of the most depressing in medicine.

The first step forward in the systematic study of the whole problem in Great Britain was the setting up of spinal units during World War II. One of these was the spinal unit at the former Ministry of Pensions Hospital, Stoke Mandeville, which started from scratch in February, 1944, but developed later into the largest unit of its kind in the British Commonwealth and Europe and has for some years been a national institution, receiving patients from all over the British Isles. It consists of six male and two female wards (with a small annexe for paraplegic children), with altogether 175 occupied beds, and deals with both service and civilian paraplegics. Associated with this centre are convalescent units and hostels in London and Eastbourne and a spinal unit at Cardiff. The principles and methods of treatment and rehabilitation of paraplegics, developed in this Centre, have been widely accepted all over the world and have served as a guide to other hospitals and units concerned with the rehabilitation of paraplegic patients. Regular post-graduate courses for nurses and physiotherapists are held, in which students from the British Commonwealth and other countries take part.

This chapter is concerned with the physical restoration of paraplegic patients. Although it deals mainly with traumatic paraplegics, the general principles can, of course, be applied to paraplegics of any cause—whether poliomyelitis, transverse myelitis, tumour, congenital abnormality such as spina bifida, or vascular processes.

Since the inception of this Centre, over 1,700 paraplegics have been treated, the majority of them (over 70 per cent.) traumatic. The mortality rate in this Centre is about 8 per cent., which includes not only everyone who died in Stoke Mandeville Hospital but also those who died after discharge home or to other institutions; it also includes paraplegics who died from causes other than the usual sequelae of a spinal cord lesion (sepsis from bedsores or urinary infection).
Avoidance of recumbency. Every endeavour is made to avoid prolonged recumbency by encouragement of all forms of movement and regular turning, even in the earliest stages after injury. This is of vital importance for the prevention of pressure sores and stagnation of waste products in the urinary tract, for the latter promotes ascending urinary infection and formation of stones in the kidneys and bladder. Any form of fixation of paraplegics with fractures of the spine in plaster casts and, in particular, plaster beds is strongly deprecated. The method of reduction of the fractured vertebra and its fixation is that of postural reduction by placing the patient on sorbo packs, with pillows underneath the fracture, and turning him regularly, in one piece, from one side on to his back and then to the other side. This is carried out by at least three people, under the supervision of an experienced sister or nurse. Details of this method have been described elsewhere (Guttmann, 1956). Fractures of the cervical spine are treated with head traction or, in certain cases, with the patient’s head fixed between sandbags only.

Nutrition. The restoration and maintenance of a good nutritional balance at the highest level is another vital point, not only in patients with septic absorption from pressure sores and infection of the urinary tract but also in patients immediately after a spinal injury. It is now well known that the loss of protein from oozing sores and urinary infection can be very great and, in the early years, some of the patients admitted to this Centre showed a state of malnutrition which could be compared only with that of victims of concentration camps. Immediate and permanent attention must be directed to the combating of nutritional deficiencies, and this is done by means of repeated blood transfusions and special diets rich in protein and vitamins.

Care of the skin. The condition of the skin in the paralysed insensitive parts of the body needs constant supervision, especially in the early stages when tissue vitality and tissue resistance to pressure are lowered because of circulatory disturbance, as the result of the traumatic shock and the loss of vasomotor control, caused by the spinal cord injury.
immediately after injury. During the war they arrived from the battle-front with gaping wounds in the back discharging cerebrospinal fluid—some of them with associated injuries to other organs, such as lungs, intestines or extremities. Since the war this group has included patients admitted from coal-mines, industry or as a result of road accidents, either immediately from the first aid post or from the hospitals where the first aid and initial treatment was given. Here, again, the patients are suffering not only from their complete or incomplete paraplegia, following fractures or fracture dislocations of the vertebra at various levels, but also from associated injuries, such as fractures of ribs, legs and arms, abdominal hemorrhage, collapse of lung, and head injuries.

The majority of paraplegics admitted, however, come in later stages, with the various complications resulting from spinal paraplegia, if the initial treatment is inadequate. These are septic conditions from pressure sores and infection of the paralysed bladder and the urinary tract. Some of these patients show signs of anemia and emaciation which may reach enormous proportions. Other complications are intractable spasticity and contractures of the paralysed limbs in extension or flexion. Many patients who are admitted in later stages are thoroughly demoralized due to prolonged and enforced inactivity in hospital or at home.

All this shows that the treatment in a spinal unit has to be very active from the beginning and is multifarious, as it embraces many aspects of medicine and surgery. The physiotherapist must be aware of these many aspects, as her work is linked with all the stages described.

The leading principle underlying the whole programme is activation and mobilization of all compensatory mechanisms in the paraplegic, in order to shift the patient’s psychomotor capabilities from the paralysed part of his body to the normal parts.

**General Treatment**

It is, of course, beyond the scope of this chapter to describe in detail the various forms of treatment, but at least the chief objects to be pursued may be mentioned.
Avoidance of recumbency. Every endeavour is made to avoid prolonged recumbency by encouragement of all forms of movement and regular turning, even in the earliest stages after injury. This is of vital importance for the prevention of pressure sores and stagnation of waste products in the urinary tract, for the latter promotes ascending urinary infection and formation of stones in the kidneys and bladder. Any form of fixation of paraplegics with fractures of the spine in plaster casts and, in particular, plaster beds is strongly deprecated. The method of reduction of the fractured vertebra and its fixation is that of postural reduction by placing the patient on sorbo packs, with pillows underneath the fracture, and turning him regularly, in one piece, from one side on to his back and then to the other side. This is carried out by at least three people, under the supervision of an experienced sister or nurse. Details of this method have been described elsewhere (Guttmann, 1956). Fractures of the cervical spine are treated with head traction or, in certain cases, with the patient's head fixed between sandbags only.

Nutrition. The restoration and maintenance of a good nutritional balance at the highest level is another vital point, not only in patients with septic absorption from pressure sores and infection of the urinary tract but also in patients immediately after a spinal injury. It is now well known that the loss of protein from oozing sores and urinary infection can be very great and, in the early years, some of the patients admitted to this Centre showed a state of malnutrition which could be compared only with that of victims of concentration camps. Immediate and permanent attention must be directed to the combating of nutritional deficiencies, and this is done by means of repeated blood transfusions and special diets rich in protein and vitamins.

Care of the skin. The condition of the skin in the paralysed insensitive parts of the body needs constant supervision, especially in the early stages when tissue vitality and tissue resistance to pressure are lowered because of circulatory disturbance, as the result of the traumatic shock and the loss of vasomotor control, caused by the spinal cord injury.
Pressure sores, which develop in particular over the bony parts of the body, may be enormous, and they are one of the most serious complications and the commonest cause of sepsis and death in paraplegics. Details of the treatment of pressure sores have been described in full elsewhere (Guttman, 1949, 1954, and 1956), and only a few points will be mentioned here.

In order to prevent the formation of sores or promote healing of those which have already developed, the patient’s position must be changed completely at frequent intervals (one to two hours), day and night. Infection of the sores is combated by various chemical and mechanical procedures, according to the nature of the infecting organisms. Necrotic portions of sores are excised carefully and the excision is followed by daily dressings. Every sore of even gigantic proportions can be healed by a combination of conservative and surgical methods. Plastic operations are, as a rule, reserved for special cases, especially those where healing has resulted in large scars. Here the physiotherapist can play a very important part in the preparation of the tissues for rotation flap operations by gentle massage of the tissues around the scars. This makes the normal tissues more pliable and helps enormously to diminish the tension of rotation flaps, when the scar is excised.

Ultra-violet light has been a popular treatment of bedsores amongst physiotherapists. We have given this form of treatment a fair trial in the past but have proved again and again that it has really no appreciable effect on the rate of healing of sores. Moreover, the danger of producing burns by this method of treatment must always be considered—the more so as the insensitive and devitalized tissues are particularly prone to burns. In this Centre, this form of treatment has been discarded.

Care of the bladder. This is just as important as the care of the skin, for ascending urinary infection from the paralysed bladder is the other main cause of sepsis and death in patients with spinal cord lesions. It is beyond the scope of this chapter to go into details of all the various local methods which are employed to counteract urinary infection, but amongst them
Physiotherapy in Spinal Paraplegia

153

urethral catheterization under scrupulous asepsis, tidal drainage, avoidance of suprapubic cystostomy, bladder washouts, and courses of antibiotics may be mentioned. Although local methods are used in the treatment of the paralysed bladder, two main factors in the treatment are the shortening of the duration of the recumbent position and the restoration of the best possible physical fitness of the patient. In lower spinal cord lesions the overdevelopment of the abdominal muscles by the physiotherapist are of great importance, as these patients express the bladder and bowels by pressure on the abdominal wall, and it is obvious that the greater the power of the abdominal muscles the better the evacuation of bladder and bowels. Many paraplegics here wear rubber urinals to become socially accepted but some can be trained to empty their bladder at regular intervals and even dispense with a urinal altogether.

Care of the bowels. This also needs greatest attention throughout and care is exercised by the use of enemas, special diets, drugs, and training the patient to attain a regular habit. In certain patients the physiotherapist might be asked to give massage to the abdominal wall and to teach him to massage himself, in order to help bowel movements. The counteraction of urinary infection, a good function of bladder and bowels and, in particular, the avoidance of distension of these organs is of greatest importance, as all these factors have great bearing on the degree of spasticity in both complete and incomplete cord lesions.

Psychological Aspects

The physiotherapist should also be familiar with the mental disorders occurring in paraplegics, either as the result of the injury or unrelated to the spinal cord lesion. They can be classified as follows:

1. Mental Disorders Related to the Spinal Cord Injury

(a) Organic mental disorders. These are caused by infective-toxic processes and are associated mainly with the infection
of the urinary tract and other organs and with septic absorption from pressure sores. They can result in increased irritability or apathy, and a real psychosis with delusions may develop.

(b) Reactive mental disorders. The sudden conversion of a vigorous person into a helpless cripple naturally leads to severe psychological shock and reactive depression due, on the one hand, to his feeling of hopelessness and, on the other, to a sense of resentment against his fate. In some cases, also, there is a tendency towards under-estimation of the extent of his disability, with consequent disillusionment and disappointment later. Some of the anxieties which may beset a paraplegic are fear of being a burden to his family and society, of being unemployable and last, but by no means least, of being sexually impotent.

2. Mental Disorders Unrelated to the Spinal Cord Injury

These can be of schizophrenic or manic-depressive type. Various types of inherent psychopathic conditions also fall within this group.

Psychological Management

From the very beginning, the patient's mental condition needs careful attention and psychological handling; the development of a strong doctor-patient relationship is the most important factor in preventing and counteracting these disorders, especially the apathy and inactivity. The patient's confidence has to be gained and his co-operation secured. The staff has to be taught to understand all the psychological reactions and to help in their treatment. The creation of a cheerful atmosphere and good morale in the ward is of vital importance. The whole unit must be impregnated with enthusiasm, for this inspires the patient to co-operate to the full. Any scheme which ignores this principle is doomed to failure. Indifference, anxiety, resentment and resignation, as well as self-deception, all have to be watched for in later stages, too, because all these disorders may impede successful rehabilitation and the patient's working efficiency. No doubt
the physiotherapist's activities are of greatest value in the psychological management of paraplegic patients.

**Physical Restoration**

The physiotherapy department is never called upon blindly for "physiotherapy, massage or remedial exercises". In every case, a constructive programme has to be devised. The physiotherapist in charge of the case receives detailed instruction about the patient's disability and the treatment to be applied by the medical officer in charge of the Centre. For, on his intimate knowledge of each case and, in particular, on his expert functional and psychological analysis of the patient's disability, depend indication, duration and modification of the various forms of physiotherapy. Attention must be paid to correlating the physiotherapist's work with that of other members of the team—the nursing staff, occupational therapists and vocational training instructors, as well as the physical training instructor, should there be one in the hospital.

The chief objects to be pursued in physiotherapy are:

1. The management of the paralysed parts of the body and;
2. The compensatory training of the normal parts of the body to compensate for the loss of the paralysed parts.

**Management of the Paralysed Parts**

1. *Position of the paralysed limbs.* The aims are to prevent contractures and prevent or diminish wasting.

   In the early stage, the physiotherapist has to assist the nursing staff in keeping the paralysed limbs in a proper position, in order to prevent flexion and adduction contracture of the legs, drop foot, claw toes, and pressure to the neck of the fibula. In cervical lesions, the proper position of the arms and hands is also of vital importance. In particular, in cervical lesions below C.6 or C.7, the habit of leaving the arms in flexion must be avoided at all costs, as, in these cases, the triceps may not be completely paralysed and sufficient
recovery may be possible to allow the upright position which, for the relative independence of tetraplegics, is of paramount importance. Flexion contractures in the elbow in tetraplegics, by overaction of the uninhibited biceps, should be regarded as a very grave professional negligence by both the nursing and the physiotherapy staff.

The permanent fixation of paralysed limbs in any position is discouraged. In lesions of the cord, the permanent position of the lower limbs in adduction and semi-flexion, by placing pillows under the knees, is deprecated as this must inevitably lead to adduction and flexion contractures. Flexion contractures of the knee and hip joints in themselves promote violent flexor spasms later, once the spinal shock, with its flaccid paralysis, has passed and the automatic reflex activity of the spinal cord below the level of the lesion has developed. The paralysed legs have to be kept for several hours in abduction and extension. In cases with cauda equina lesions, if the care of the patient's position in the early stages has been neglected, contractures often develop in flexion of the hip, extension of the knee and adduction of the leg. This occurs in particular in lesions below L.2, in which the intact muscles—iliopsoas, adductors and internal rotators—have an unrestrained over-action, due to the paralysis of their antagonists.

The most deleterious type of contractures was found in the cases admitted in plaster beds, in which the patient had lain for many months. At the beginning of the recent war, plaster beds were advocated for the prevention and healing of pressure sores. Experience has shown that not only have plaster beds proved to be no better method for encouraging the healing of sores but, in all cases admitted, they have actually promoted the development of sores. In addition, the contractures of the joints and the atrophy of the tissues of the back, caused by this type of fixation, were profound. Patients who had recovered from cord or cauda equina symptoms were frustrated because of the superimposed contractures of the joints and the distortion of the pelvis, developed in plaster beds. However, it must be emphasized that hyperlordosis with distortion of the pelvis may also develop, particularly in children or young adults, when the position
of the paralysed patient has been neglected in the early stages.

2. Passive movements. Passive movements of all joints of the paralysed limbs are begun almost immediately after injury and are carried out at least twice daily, in order to prevent contractures and promote better circulation in the paralysed limbs. Passive movements of the paralysed limbs are also accomplished by frequent change of posture, which also promotes better circulation. It is obvious that, in a busy spinal ward, the physiotherapist cannot possibly be responsible alone for carrying out passive movements, and she has to encourage the nursing staff to co-operate in this important function. This applies particularly in tetraplegics, with regard to positioning of the upper limbs, as mentioned above. The beneficial effect of regular passive movements in overcoming even most severe contractures in patients admitted to the Centre in later stages, has been sometimes quite amazing. The effect of treatment is judged by weekly or fortnightly measurements, which can be charted.

3. Electrotherapy. Daily electrical stimulation by interrupted direct current or other forms of electrical current is included in the programme of physiotherapy, in certain groups of paraplegics with lower motor neurone lesions, such as of cervical roots, cauda equina or anterior horns. In these cases, electrotherapy is used only as a substitute for active exercise and has proved beneficial in promoting better circulation in the paralysed muscles, in preventing extreme degrees of atrophy and fibrosis and in preserving good contractile power. This is true particularly in muscles with partial denervation and in those with total denervation in which re-innervation occurs. Electrical stimulation is started as early as possible (about five days after injury) and is applied at least once, and in some cases twice, daily in gradually increasing number of contractions, starting with 50 to 100 per session. In due course, as many as 600 to 800 and more contractions can be applied to paralysed muscle groups, during a session of about 30 to 45 minutes. Care should be taken to elicit powerful contractions separated by resting periods of a few seconds. In early stages of lower
recovery may be possible to allow the upright position which, for the relative independence of tetraplegics, is of paramount importance. Flexion contractures in the elbow in tetraplegics, by overaction of the uninhibited biceps, should be regarded as a very grave professional negligence by both the nursing and the physiotherapy staff.

The permanent fixation of paralysed limbs in any position is discouraged. In lesions of the cord, the permanent position of the lower limbs in adduction and semi-flexion, by placing pillows under the knees, is deprecated as this must inevitably lead to adduction and flexion contractures. Flexion contractures of the knee and hip joints in themselves promote violent flexor spasms later, once the spinal shock, with its flaccid paralysis, has passed and the automatic reflex activity of the spinal cord below the level of the lesion has developed. The paralysed legs have to be kept for several hours in abduction and extension. In cases with cauda equina lesions, if the care of the patient's position in the early stages has been neglected, contractures often develop in flexion of the hip, extension of the knee and adduction of the leg. This occurs in particular in lesions below L2, in which the intact muscles—iliopsoas, adductors and internal rotators—have an unrestrained over-action, due to the paralysis of their antagonists.

The most deleterious type of contractures was found in the cases admitted in plaster beds, in which the patient had lain for many months. At the beginning of the recent war, plaster beds were advocated for the prevention and healing of pressure sores. Experience has shown that not only have plaster beds proved to be no better method for encouraging the healing of sores but, in all cases admitted, they have actually promoted the development of sores. In addition, the contractures of the joints and the atrophy of the tissues of the back, caused by this type of fixation, were profound. Patients who had recovered from cord or cauda equina symptoms were frustrated because of the superimposed contractures of the joints and the distortion of the pelvis, developed in plaster beds. However, it must be emphasized that hyperlordosis with distortion of the pelvis may also develop, particularly in children or young adults, when the position
of the paralysed patient has been neglected in the early stages.

2. Passive movements. Passive movements of all joints of the paralysed limbs are begun almost immediately after injury and are carried out at least twice daily, in order to prevent contractures and promote better circulation in the paralysed limbs. Passive movements of the paralysed limbs are also accomplished by frequent change of posture, which also promotes better circulation. It is obvious that, in a busy spinal ward, the physiotherapist cannot possibly be responsible alone for carrying out passive movements, and she has to encourage the nursing staff to co-operate in this important function. This applies particularly in tetraplegics, with regard to positioning of the upper limbs, as mentioned above. The beneficial effect of regular passive movements in overcoming even most severe contractures in patients admitted to the Centre in later stages, has been sometimes quite amazing. The effect of treatment is judged by weekly or fortnightly measurements, which can be charted.

3. Electrotherapy. Daily electrical stimulation by interrupted direct current or other forms of electrical current is included in the programme of physiotherapy, in certain groups of paraplegics with lower motor neurone lesions, such as of cervical roots, cauda equina or anterior horns. In these cases, electrotherapy is used only as a substitute for active exercise and has proved beneficial in promoting better circulation in the paralysed muscles, in preventing extreme degrees of atrophy and fibrosis and in preserving good contractile power. This is true particularly in muscles with partial denervation and in those with total denervation in which re-innervation occurs. Electrical stimulation is started as early as possible (about five days after injury) and is applied at least once, and in some cases twice, daily in gradually increasing number of contractions, starting with 50 to 100 per session. In due course, as many as 600 to 800 and more contractions can be applied to paralysed muscle groups, during a session of about 30 to 45 minutes. Care should be taken to elicit powerful contractions separated by resting periods of a few seconds. In early stages of lower
motor neurone lesions the denervated muscles still react to faradism, and this type of current may be used. As soon as complete R.D. develops the faradic stimulation should be replaced by interrupted direct current. Since the skin resistance decreases during electrical stimulation, the same vigorous contraction can be obtained by progressively weaker current strength. The electrodes should not be restricted to one position but should be repeatedly altered to avoid local damage by burning the underlying tissues, and thus the current is directed to various parts of the muscle. If depolarized impulses are used the danger of burning is eliminated or greatly diminished. However, this is altogether avoided if the active electrode is moved and stroking stimuli are applied along the length of the whole muscle. Moreover, this technique guarantees the inclusion of all muscle fibres in the electrical stimulation.

Finally, it may be emphasized that the denervated muscle needs a similar individual training by electrical stimulation as does the normal or recovering muscle by active exercise. However, whatever the individual differences in muscle behaviour, the fear of over-fatiguing denervated muscles by frequent stimulation has been grossly exaggerated in the past and has led all too often to quite useless application of electrotherapy, such as ten contractions only. Electrical stimulation should be continued until re-innervation and voluntary control of the muscles occurs and active exercise becomes possible.

4. Treatment of flexor spasms. This problem in the treatment of spinal cord injuries requires more detailed discussion here. Violent reflex spasms—in particular, flexor spasms of the lower limbs—develop in many cases once that part of the spinal cord which is below the level of the lesion has recovered from spinal shock and has taken up its autonomous function, unrestrained by the control of the pyramidal tracts and other centrifugal pathways. A number of intrinsic and extrinsic factors may act as noceceptive stimuli, which, entering the spinal cord below the level of the lesion as afferent impulses, are transmitted to the anterior horn cells and other efferent systems and elicit a mass response, of
which the reflex spasms of the motor apparatus is one of the various associated conditions, such as sweating, vasoconstriction, bladder and bowel evacuation, and penile erection.

The importance of the various intrinsic and extrinsic factors in lowering the threshold of reflex activity of the damaged spinal cord must be remembered in spinal injuries from the onset, in relation to the prevention and treatment of flexor spasms. Some of these factors may be mentioned here. Distension of the paralysed bladder is a violent initiator of the reflex spasms, and the smaller the capacity of the bladder the smaller the amount of urine necessary to elicit a reflex response. Of equal importance is the distension of the rectum and colon by stagnation of faeces. Indeed, the beneficial effects of evacuation of an overloaded rectum by means of enemas on the intensity of flexor spasms are often very striking, as is also the prevention of stagnation of faeces in higher parts of the colon by the administration of liquid paraffin. Any intervening infection (in particular that of the urinary tract), septic absorption from pressure sores, and anaemia also lower the threshold of reflex activity of the spinal cord, and conversely the successful treatment of these factors also diminishes the intensity of reflex spasms. The importance of the irritation of sensory organs in contracted joints and tendons for the facilitation of spasms is another factor and is already mentioned above.

Prevention of contractures in the early stages of paraplegia, by correct positioning of the paralysed limbs, has already been mentioned. Once contractures have developed, regular passive movements have proved to be the most successful form of treatment in our cases. It must be emphasized that even extreme degrees of flexor spasms and contracture in paraplegics can be greatly improved by this conservative measure, especially if the passive movements are carried out in a continuous bath or in a swimming pool kept at a uniform temperature. Another method which has proved very useful, especially if no swimming pool is available, is the Stoke Mandeville Bed Cycle, designed by one of us (L. G.). A further method of overcoming flexor spasms and contractures is fixation of the paralysed limbs in extension and
abduction by strapping the patient for increasing periods whilst lying either in bed or on a plinth. In this connection, placing the patient in the prone position is very often of great advantage, as this position encourages the extensor reflexes of the body.

A number of surgical measures, such as division and elongation of tendons of the flexor muscles of the toes, feet or knees, division of the obturator nerves in cases where the adductor spasms are preponderant, and the division of anterior or posterior roots following laminectomy have been recommended. These surgical procedures have their indication in selected cases and have proved to be successful, especially if followed by passive movements. In complete lesions, with intractable spasticity, the intrathecal block, as introduced in 1946 by one of us (L. G.) has proved a blessing for these patients, since this procedure has replaced destructive operations, such as anterior or posterior rhizotomies.

Adaptation Therapy of Normal Parts of the Body

General Principles of Compensatory Training

These are carried out, from the early stages, in conjunction with passive movements of the paralysed limbs, with a view to over-development of those muscles which are essential for the patient’s upright position, the readjustment of the postural control and the vasomotor control of these cases.

1. Overdevelopment of arm, trunk and abdominal muscles. From the start emphasis is laid on exercise of those muscles which are essential for the patient’s upright position, especially those with attachment to the pelvis. The most important muscles to be exercised in spinal cord lesions above T.7 are the latissimus dorsi, trapezius, teres major, serratus anterior, pectorals, and last but no means least, the triceps—and, for distal cord lesions, also the abdominal and long back muscles. Compensatory training of these muscle groups is important for the following reasons:

(a) the combined operation of these muscle groups will greatly improve the balance and mobility of the trunk:
(b) strong action of these muscles will help to shift the psychomotor capabilities in the paraplegic from the paralyzed distal parts to the upper parts of the body, because it makes the activity of the normal upper muscles more effective, owing to increased fixation of the trunk:

(c) the combined operation in these muscle groups will restore the capability of the paraplegic to walk between parallel bars or on crutches, by means of pelvic tilting or by promoting swinging movements of the trunk. The knees are fixed with light bivalved walking plasters and, later on, with calipers, keeping the feet at the correct angle by means of simple toe-raising springs; thus, the paralysed legs are used as stilts:

(d) training of the abdominal muscles is, as already pointed out, of great importance for the re-education of the bladder and for the restoration of the sexual function of the paraplegic.

2. Re-orientation of postural sensibility and co-ordination mechanisms. It must be remembered that, in complete lesions of the cord, the loss of postural sensibility in the hip joints, amongst other disturbances of sensibility, makes a paraplegic unable to keep his balance. Therefore, new afferent impulses subserving postural control have to be developed along the normal nerve fibres in the latissimus dorsi and other back muscles, to reconnect the paralysed part of the body with the central mechanisms in the brain and cerebellum subserving postural control.

3. Readjustment of vasomotor control. The vasomotor control is crippled in paraplegics with lesions above T.5 by the interruption of the efferent part of the splanchnic outflow. The result of this is the mal-adaptation of the paralysed to change of posture, and such a patient, when raised from the horizontal to the upright position, will tolerate this position very badly, owing to the rapid and uninhibited accumulation of blood in the abdominal area and the lower limbs, as a result of the paralysis of the vasoconstrictors, and this results
in a decrease in the venous return with consequent insufficient cardiac output. As a result, the patient faints. However, it was found that this disturbance of vasomotor control could be overcome by exercises, which include frequent change of posture, swinging in suspension and breathing exercises, which will be discussed later. By these means, forces of the vasomotor adjustment, which are regulated by the carotid sinus and other blood collectors, are developed to act as "emergency adaptors", in order to compensate for the loss of the splanchnic control.

Special Methods of Compensatory Training

The following are special methods which have been developed at Stoke Mandeville to achieve compensatory training effects:

1. Suspension exercises. Auto-assisted movements are introduced in the early stages, while the patient is still in bed, with the help of simple spring units, and ten pulls or more are made by the patient every half an hour to an hour. Later on, exercises in suspension and against resistance, by means of pulleys and weights, are added. The Guthrie-Smith apparatus has proved invaluable for these exercises. Plate IX shows a patient, with a complete lesion below T.3, conveniently suspended in such a position as to allow movements unhindered by friction or weight of the paralysed body, doing suspended exercises in such an apparatus. The arms are elevated and the hands are holding on to the upright bar. In cervical lesions, with paralysis of the flexors of the fingers, the hands may either be bandaged on to the bar or the patient will hook his wrist or elbow round the bar, giving himself a fixed point from which to work. Care must be taken that the pelvic sling does not produce friction to the sacrum, especially in the presence of scars from healed pressure sores, and a pillow must be placed between the patient and the sling. Patients wearing a rubber urinal must be suspended with the legs lower than the pelvis, in order to prevent back-flow of urine from the urinal into the trousers. In patients with severe flexor spasms, the legs will have to be
kept in extension by well-padded splints. The patient first learns to swing his pelvis from side to side, by action of the shoulder muscles and pectorals and particularly trapezius, latissimus dorsi and triceps. The same effect can be achieved by suspension exercises, once the patient can sit in a wheelchair. His arms are suspended in abduction by an elbow sling and overhead rod, to which a spring is also attached, and he can exercise his shoulder muscles against resistance. Furthermore, the power of the back and abdominal muscles can be increased by suspension exercises in sitting position, on a plinth, as shown in Plate IX B. In due course, the back muscles and pectorals may reach a state of hypertrophy which is sometimes quite grotesque, as seen in Plates X A and A in a case of complete transverse lesion below T.6.

2. The Stoke Mandeville bed cycle. This apparatus has a wide application in the treatment and rehabilitation of patients suffering from paralysis, contractures and spasticity. This apparatus was mainly designed for patients still confined to bed, but it is now used in the physiotherapy department as an essential piece of equipment for patients needing this type of physiotherapy. By promoting self-induced exercise to the paralysed muscles of trunk and legs, through the medium of interconnected hand and leg-operated cranks, the bed-cycle has become invaluable in achieving a variety of effects. It improves the power of the trunk muscles and, in particular, the trapezius. It has a profound effect on improving the blood circulation in both the normal and the paralysed parts of the body. Its use is a most physiological exercise in overcoming contractures, not only in paraplegics but also in rheumatic patients, and, lastly it has a beneficial effect on spasticity, by causing fatigue in the spastic muscles. A detailed description of the apparatus has been published elsewhere (Guttmann, 1949).

3. Balancing exercises. These exercises are carried out to restore postural sensibility and upright position. The patient first sits in front of a mirror and raises the arms alternately in various directions under visual guidance. Later on, owing to the fact that proprioceptive impulses arising from any movement of the pelvis are transmitted centrally along the nerve
fibres in the latissimus dorsi and other back muscles, the patient is enabled gradually to develop a new pattern of postural sensibility. Eventually, he can keep his upright position without the aid of visual guidance and can raise his arms with his eyes closed.

In the second stage of restoration of posture, the paraplegic is taught to keep his balance, when throwing and catching a ball or sandbags.

The final stage is one of vigorous punch-ball exercise, which comprises repeated alternations between free movements and movements against resistance.

Balancing exercises are also carried out in standing position and for improving the patient's confidence and skill. At the beginning, they are carried out in front of a mirror—first in parallel bars and, later on, on crutches. The patient leans on one crutch and lifts the other forwards, sideways and upwards.

4. **Dressing exercises.** Another example of exercise, to adjust paraplegics to postural changes whilst in bed and to prepare for their future independence, are dressing exercises. The paralysed patient is taught and encouraged to dress himself in the minimum of time, the procedure including boisting himself from his bed to his wheel-chair, either with or without the aid of chain and handle fixed on a pole over his bed. Both the physiotherapist and the nursing staff take their share in training the patient in this exercise. A well-trained paraplegic, with a complete transverse lesion at T.10 or below, should be able to dress himself in about 8 to 10 minutes; this includes putting on his shoes and calipers.

5. **Walking exercises.** When the muscle power in the normal parts and the balance of the body have improved sufficiently, standing and walking exercises are begun between parallel bars or in walking chairs, followed by walking on arm and elbow crutches. The walking chair used for paraplegics in this Centre, designed by one of us (L. G.), is fitted with hand-brakes on either side, which increases the safety and stability of the chair and gives the paraplegic more confidence. Moreover, it enables him to walk not only in a forwards direction but, by putting on one brake only, also to turn
towards the side of that brake. The chair is also equipped with a comfortable seat for resting during exercise Plate XIA.

In most paraplegics, even those with complete lesions of the upper thoracic and lower cervical cord (C.7/C.8), walking capabilities can be restored to varying degrees. Walking exercises are started in parallel bars and continued in a walking chair, before the patient graduates to crutch-walking. In all these exercises, time and distance are gradually increased. Naturally, the walking capabilities of a paraplegic, especially those with higher lesions, still remain limited. But, however slight they may be, they greatly increase his self-confidence, range of activity and independence at home and place of employment. It is very important that the physiotherapist stresses the importance of continuing the walking, even if only as an exercise, once the patient has returned home, as many paraplegics tend to give up standing and walking once they have left hospital.

The following types of walking are taught, as routine, in the Centre:

(a) Four-point gait. The patient moves his left hand forwards along the bar, then swings the right leg through, by tilting the pelvis upwards. He now transfers the body-weight on to the right leg, moves his right hand forwards and swings his left leg through, by tilting the left side of the pelvis upwards. This type of gait, although slow, is by far the safest when walking with the aid of arm or elbow crutches—particularly for lesions above T.10.

(b) Swing-to gait. This gait is a quicker form of locomotion than the four-point gait and is also less strenuous in lesions at mid or higher thoracic levels. The hands, which are placed on the parallel bars or grasping crutches, are moved forwards either separately or simultaneously and the body then lifted and pulled forwards a short distance, so that the feet always remain behind the level of the arms and crutches. Thus, a firm triangular base is established, which prevents overbalancing in a forward direction.

(c) Swing-through gait. This type of gait is especially used in lower cord lesions (as a rule, below T.10), but paraplegics
with higher lesions up to T.5 have succeeded in learning this form of locomotion, if the paralysis was not interfered with by spasticity. The arms and crutches are moved forwards and the body is then swung through in front of the arms and crutches, the hips and spine being held in extension. Then, the arms and upper trunk are swung forwards simultaneously so that a firm triangular base is established, and then the legs and body are swung forwards again. The swing-through gait undoubtedly represents the quickest form of locomotion in paraplegics.

6. Calipers. Whatever the type of caliper or brace indicated, the greatest attention should be paid to its weight, which should be as little as possible. It must be remembered that paraplegics have already to lift and to move the paralyzed part of the body, with the remaining normal muscles, and it is, therefore, quite obvious that every ounce of additional weight counts and means a further burden to the patient, causing fatigue and incapacity. The metal parts of the caliper should be made of duralumin or, even better, hiduminium, which has a higher degree of durability than the duralumin. The fasteners should be of buckle type and not lacing.

In most paraplegics—even those with lesions at higher levels—non-weight bearing type of calipers are used, without pelvic bands or braces (Plate XIB). In this respect, our views differ from those held in the U.S.A., where braces are prescribed indiscriminately by some authors. As a rule we prescribe braces only for paraplegics who develop scoliosis.

7. Crutches. Crutches, especially elbow crutches, should also be as light as possible and of telescopic type.

Management of Respiratory Disturbances in Higher Dorsal and Cervical Lesions

The higher the cord lesion the greater the patient's dependence upon the action of the diaphragm and accessory muscles for his major respiratory function. This applies in particular to cervical lesions above C.7. In order to increase the vital capacity of the lungs, the patient must be
taught to use the remaining respiratory muscles to the fullest possible capacity, and maximal apical inspiration must always be encouraged, as well as diaphragmatic breathing. These patients are particularly endangered if they develop congestion of the lungs. The physiotherapist's main role in these cases is basically the same as that for any other acute chest condition, in that she helps the patient to cough and expectorate mucus accumulated in the lungs. The importance of a close co-operation between nursing and physiotherapy staff in these acute cases cannot be over-emphasized, as each is dependent on the good will of the other. As the patient is turned by the nursing staff at regular intervals, the physiotherapist must know the time of these turns and must fit in her work accordingly—the more so as the respiratory treatment in these cases has to be carried out very frequently. It is better to treat such a patient for short periods but often, rather than give him two or three long sessions. It may be necessary, in some cases, to elevate the foot end of the bed in order to drain the chest more fully from the lower lobes.

In order to improve the function of the diaphragm in cervical lesions the physiotherapist must fix the diaphragm with her hands by applying pressure during expiration, in order to compensate for the loss of the abdominal muscles which normally, by their resistance, facilitate the action of the diaphragm. As the physiotherapist places her hands over the lower lobe and on the lower chest wall, the patient takes a deep breath in, and, as he breathes out with forced expiration, the physiotherapist vibrates the chest wall, giving maximal pressure at the end of each expiration. After this has been repeated several times, the physiotherapist then tells the patient to breathe out as far as possible and then to cough, trying at the same time to expectorate the loose mucus from his chest. As he coughs, she slides her hands down from the lower rib cage, so that she can give pressure over the upper part of the abdomen, in order to replace the function of the paralysed abdominal muscles. It may be noted that, in transverse lesions of the cervical and upper thoracic cord, although the intercostal muscles are completely
paralysed, their tone recovers to some extent, in later stages, and, once the spinal cord below the level of the lesion regains its automatic function, these muscles may become active by reflex action.

Glossopharyngeal breathing, also called "frog" breathing or "gulping", is used as a substitute for breathing in high cervical lesions (particularly due to poliomyelitis), in which there is a paralysis or weakness of both intercostals and diaphragm. It makes use of the function of the mouth and throat muscles to act as a pump, to force air into the lungs. A special technique of this type of breathing has been described by Clarence W. Dale (1951).

**Games and Sport**

Games are very important in the physical, psychological and social readjustment of paraplegics. In recent years, sport has been included in the rehabilitation of paraplegics to an increasing degree, as an addition to the conventional physiotherapy methods, and it is felt that, in the syllabus for training of physiotherapists, more attention should be paid to this form of remedial exercise. A large number of games, such as basketball, javelin-throwing, putting the shot, table tennis, fencing (both sabre and foil), snooker and, in particular, archery can be adapted to the abilities of paraplegics. In this Centre, the importance of sport in the rehabilitation of paraplegics has been recognized from the start, and in 1948 an annual sports event was founded by one of us (L. G.) called the Stoke Mandeville Games. This sports event has developed into the first international sports movement for the disabled, and from year to year both the number of sports events and the number of competitors taking part have increased. At the 1957 Stoke Mandeville Games, 360 competitors representing 24 nations came to take part in the competitions, travelling from all over the world. (Plate XII demonstrates the archery competition at the 1957 Games.) National and international sports organizations of the able-bodied have not only taken notice of this unique sports movement for the paralysed but have even shown their
(A) Suspension for exercises in a case of complete transverse spinal lesion at T.3.

(B) Strong resistance exercise for the back extensors.
(A) Hypertrophy of pectoral muscles in a case of complete transverse spinal lesion at T.6. Note the contrast between this hypertrophy and the extreme atrophy of the intercostal and abdominal muscles.

(B) The same patient showing hypertrophy of the upper back muscles.
The archery competition at the 1937 International Games at Stoke Mandeville.
appreciation of its humanitarian work. The International Olympic Committee, at the Olympic Games in Melbourne, awarded the Fearnley Cup for 1956 to the Stoke Mandeville Games. This is an Olympic Award given to any sports organization in any country for outstanding achievement in the service of the Olympic Movement, and it is the first time in the history of sport that this great Olympic honour has been awarded to a sports organization for the disabled.

References


CHAPTER 16

Rehabilitation after Amputation

BY O. S. THOMPSON, M.CH.

The purport of this chapter is intended to be a practical approach to the rehabilitation of the amputee patient from the physiotherapist’s angle rather than a conventional review of routine post-operative amputation stump management. Perhaps in no other branch of systematic therapy is rational objectivity more essential than in the planned restoration of ambulatory function to a patient who has lost one or both lower extremities.

In non-amputee limb cases the physiotherapist concentrates remedial efforts on tissues still evidencing the scars of trauma or disease. In amputation cases the causal pathology, the diseased or devitalized limb section has been removed, and speaking “ideally”, the amputation stump should as far as possible, be an abbreviated section of normal anatomy. The stump muscles may be shrunken and atomic from temporary disuse and thus deprived to varying degrees of control of limb alignment, but there should be no tissue pathology in the stump, nor should it be created.

The purpose of amputation surgery is to rid the body of an irretrievably devitalized limb caused by malignant disease, irreparable bone or joint tuberculosis, or of one so hopelessly affected by chronic sepsis as to menace constitutional good health. Amputations for flail limbs, the residual palsy of anterior poliomyelitis and the problems of congenital deformities are special considerations.

The object of treatment is simple and most clearly defined. It is not merely a question of exercising an amputation stump as is so often thought, but to restore to the patient, not to the amputation stump, the motor function of ambulation
or, in the upper extremity that of manual control, be it coarse, medium or precision. It must therefore be remembered that although a major portion of the limb extremity has been removed, the cerebral centres regulating movement control, planning co-ordinated action, or housing the art and cunning of experienced skilled craftsmanship remain unimpaired. But again it is to be remembered that in obedient response to the direction of these centres the remains of the erstwhile limb is now called upon to activate an artificial limb prosthesis to maximum advantage in power, versatility and range of movement. The physiotherapist occupies an intermediate position and, indeed, one of no mean responsibility between the surgical and nursing staff on the one hand and the Limb Fitting Service on the other.

In former days, especially before the First World War, limb amputation was often considered the "point of no return" for the patient, but in more enlightened times, especially with patients in employable age groups and rapidly growing child patients, it is really only the first phase of planned rehabilitation. The second phase—the interval from operation recovery to supply of the artificial limb is the physiotherapist's field of activity. During this period, indifferent handling of the convalescent patient may not only discount good surgical efforts but also prejudice ultimate restoration of motor function. The third phase, or the supply and instruction in the use of an artificial limb, thus depends for success or failure on the efforts in the preceding phases.

**Approach to Treatment**

The golden rule to be observed by every rehabilitation team is "Think always of the amputee patient as an entirety and never in terms only of an amputation stump, or, worse still, of an artificial limb, and never derogate him as a cripple. He is temporarily disabled perhaps, but he is not crippled."

Thus following amputation, an acceptable working arrangement presents itself as:

1. Preparation of the patient.
The purport of this chapter is intended to be a practical approach to the rehabilitation of the amputee patient from the physiotherapist’s angle rather than a conventional review of routine post-operative amputation stump management. Perhaps in no other branch of systematic therapy is rational objectivity more essential than in the planned restoration of ambulatory function to a patient who has lost one or both lower extremities.

In non-amputee limb cases the physiotherapist concentrates remedial efforts on tissues still evidencing the scars of trauma or disease. In amputation cases the causal pathology, the diseased or devitalized limb section has been removed, and speaking “ideally”, the amputation stump should as far as possible, be an abbreviated section of normal anatomy. The stump muscles may be shrunken and atonic from temporary disuse and thus deprived to varying degrees of control of limb alignment, but there should be no tissue pathology in the stump, nor should it be created.

The purpose of amputation surgery is to rid the body of an irretrievably devitalized limb caused by malignant disease, irreparable bone or joint tuberculosis, or of one so hopelessly affected by chronic sepsis as to menace constitutional good health. Amputations for flail limbs, the residual palsies of anterior poliomyelitis and the problems of congenital deformities are special considerations.

The object of treatment is simple and most clearly defined. It is not merely a question of exercising an amputation stump as is so often thought, but to restore to the patient, not to the amputation stump, the motor function of ambulation...
Except for the firm and steady pressure of a stump bandage (see p. 187), stump tissue tension in the recovery phase should be regulated entirely by the active movements of the stump muscle. In this way one of the predisposing causes of painful stump and painful phantom limb may be avoided.

Immediate post-operative treatment. This, in the first instance, must naturally be the responsibility of the medical and nursing staff, but within 24 to 48 hours, the physiotherapist becomes engaged in allied duties. The stump wound dressing following operation is usually gauze and elastoplast and a firm crepe bandage over adequate cotton wool is a precaution against ooze of blood and minor trauma discomfort. The above-knee stump must be allowed to lie flat on the bed, being protected by a bed cradle, and any tendency to flexion can be counteracted by sandbags on either side with a towel anchorage. In below-knee cases, the knee joint is fully extended and bandaged to a long posterior splint. Within about 48 hours the patient accepts the extended stump position, assisted obviously by the lessening of flexor muscle spasm.

At no time must a sandbag or pillow be placed under the stump even though it may ease tension.

Physical preparation. This covers a primary period whilst in bed from 24 to 48 hours to 10 days after operation. It comprises regulated exercises designed for the general physical "toning up" of those who have suffered amputation of the lower or upper extremity, or both, in order that they shall be fit to undergo the added exertion of artificial limb wearing. The prescription, frequency and intensity of exercises accords with orthodox practice but should be regulated and adapted to the clinical considerations of age, mentality and constitutional physique.

In times of war the younger age group predominates and the patients are bodily fit and healthy. At other times the age incidence of primary lower extremity amputees is much higher: in the sixties and beyond, as amputation is invariably necessitated by peripheral vascular deficiency, with or without the metabolic complication of diabetes or other
2. Preparation of the stump.
3. Instruction in the use of an appropriate prosthesis.

Preparation of the Patient

It may truly be said from the physical and psychological aspects that the first week after amputation is the vital and vulnerable period for the patient. In former times following operation the emphasis was directed towards inactivity and complete bodily relaxation, with the inevitable result that convalescence was unduly if not indefinitely prolonged and hopes of successful rehabilitation doomed to failure. The patient was often returned to bed from the operating theatre, and if there were no untoward complications the stump wound stitches were removed about the tenth day and the patient was then allowed a further period in bed to reconcile himself to his obvious misfortune. Invariably a pillow or sandbag, placed misguidedlly but with good intention under the stump, would provide additional comfort to the patient. With equally good intentions a massage enthusiast might “lay on hands” or commit “assault and battery” on the defenceless, healed or unhealed stump, with indifferent results. Eventually the patient was taken from bed, introduced to crutches of indeterminate length, and, forthwith, collapsed. The clinical picture portrayed a pallid, breathless, perspiring, apprehensive patient, with a depleted cardiorespiratory reserve, a flabby abdomen, a weak atonic “sound” leg and to cap everything a swollen stump held in flexion contracture.

According to modern teaching, massage of the amputation stump at any period is regarded with disfavour. Amputation surgery is based on a sharp, clean-cut division through healthy tissue acting on the principle “the cleaner the cut, the less the tissue contusion and reactionary fibrosis” particularly in regard to divided nerve trunks. Every effort is made to reduce surgical trauma to the inescapable minimum, whilst massage, which is a form of applied trauma, merely serves to increase the reaction.
particularly during the balance re-education, walking training period.

Mental preparation. Whilst planning the general exercise programme, the physiotherapist should also consider the mental factors associated with the patient and they may indeed be very evident. The loss of a limb is undoubtedly a great mental shock to the patient especially when resulting from trauma in the younger and employable age group. Family and employment problems loom heavily, and rehabilitation must therefore be expedited at top speed if anxiety and despair for the future is to be avoided.

The patient should be ready for limb-fitting consideration within a month of operation, and it is to his advantage to attend the Limb Fitting Centre as early as possible in order to see for himself the progress, achievement and independence of other arm or leg amputees. To satisfy himself that he can do what others of similar disablement can do, and do it equally well, is the greatest incentive to "patient-therapist" cooperation, and hence the advantage of community training in the efficient use of an artificial arm or leg.

The young traumatic case is generally in good physical condition, more mentally alert and thus more responsive to early rehabilitation exercises, but although general muscular atony is less apparent than in the older groups, bodily toning up exercises should not be omitted. The secret of success from the mental angle is an occupied mind and the assurance that not only is everything being done by the rehabilitation team to expedite his return to employment and the amenities of normal living, but that such is obvious beyond doubt.

The other mental consideration arises in the case of the elderly patient. Most are co-operative, in fact often enjoy extravagant views regarding their recuperative faculties, but it is to be remembered that the peripheral lesion of the constitutional disease impairing the nutrition and vascularity of the affected limb may also interfere with the patient's mental acuity and perceptive appreciation. This extra burden, added to poor physical reserve may prolong the rehabilitation period and a disconsolate or a disheartened patient is
nutritional disturbance. In these older cases it is noted that the patient suffers from the disease as a constitutional disorder, but the clinical manifestation is revealed locally in the gangrenous or pre-gangrenous extremity. Therefore a word of warning—the causal disease is general and its debilitating effects are present to greater or lesser extent in other vital tissues of heart, brain, lungs and central nervous system.

Immobility, inactivity, prolonged sitting in an invalid chair or long, often too long, periods in bed are bound to cause stiffness and restricted movements in all joints, large and small, with resultant postural mal-alignment. However, provided there is no organic skeletal disease already present, restoration of normal posture and joint suppleness is not an insurmountable problem. It is really a case of loosening up and limbering up, even with the elderly, but with the proviso of caution.

Whilst in bed, the exercises are gentle and graduated but nevertheless definite. They are followed by more vigorous exercises when the amputation stump has healed soundly and the patient is ambulatory mobile on crutches. During early treatment the cardiorespiratory effort-tolerance must be improved and breathing exercises are essential. The shoulder girdle, neck, spine and abdominal muscles are equally important, as it is common knowledge that good comfortable walking depends on good postural carriage of head, shoulder and trunk, and routine exercises are directed to that purpose (Figs. 95 to 99 and 101).

In lower extremity amputees the muscles of the remaining leg demand equal attention to those of the stump, as it is desirable to get the patient up on crutches as soon as the stump is healed, or in any case 10 days after operation if his general condition permits.

A strong sound leg is essential for the satisfactory wearing of an artificial limb and intensive exercises with or without resistance apparatus are always necessary. Suitable exercises are shown in Figs. 81, 83 and 84. Finally the extensor group of muscles acting over the joint proximal to the site of amputation must be exercised. It is also to be remembered that the loss of a leg demands added strength in the arms
(A) Flexion contracture. Loss of extension 30°.

(B) Forward thrust of patient and slight lordosis necessary to bring stump into alignment with the natural leg.
not an easy one. But whilst there is a reasoned and reasonable possibility of securing independent mobility, efforts are always well worth while.

Too much too quickly should not be expected of the older patients. The limit of prosthetic expectation may be little more than domestic “shuffling about”, but even this may be preferable to a permanent bed-ridden or chairborne existence. The nursing attendance requirements of an aged, immobilized amputee patient can be very onerous.

**Preparation of the Amputation Stump for Artificial Limb Wearing**

The needs of the patient as an individual having been stipulated, the physiotherapist now directs attention to the amputation stump, thinking in terms of anatomical contour, active muscle power, range and freedom of proximal joint movement, ease of handling and absence of discomfort. With the object of securing a normal or near normal gait for the patient, and one which does not attract the interest and attention of the sympathetic or curious passer-by, these several stump considerations will eventually be correlated with the fit, function, suspension, activation and control of the artificial limb. In upper extremity stumps similar considerations obtain in order that the patient may reproduce the lost motor function of the hand.

The approach to these objectives resolves itself into:

1. **Stump exercises**,  
2. **Stump bandaging**,

and the reasons are clearly significant.

**Stump Exercises**

The purpose is to maintain, or if lost, to restore, the full pre-amputation range of proximal joint movement and thereby prevent or rectify stump malposition resulting from over-powerful and over-active antagonist muscle groups which have escaped the trauma of amputation surgery. As an
example, flexion contracture of an above-knee stump reduces the range of hip extension, thereby reducing the length of the gait.

With malposition of the stump there is coincident passive stretching of the muscle fibres of the weaker group which slowly and insidiously lose muscle tone and contractile power. Muscle stretching is therefore to be prevented in order that full muscle tone and full residual efficiency in the sectioned muscle may be preserved. In restoring or maintaining full proximal joint movement, antagonist, e.g. flexor-extensor, muscle equilibrium, is also achieved and the stump assumes a position of tonal rest in normal anatomical relation to natural limb alignment.

Attention is next focused on improving the general motor power of the stump for use in activation of the limb. This is equally important for the patient's safety and stability in the selective control of the activated prosthesis. The preparation of the stump should normally start at the end of 24 hours, but again the utmost caution is to be observed as the first consideration must be the uneventful and uninterrupted healing of the amputation wound and all forms of therapy must be regulated to that purpose.

Gentle active stump movements are initiated as early as possible, at first for short periods of a few minutes only at lengthy intervals twice or three times a day, gradually increasing to longer periods, more frequently through a greater range of joint movement, but never to the extent that the patient complains of pain or a feeling of tension in the stump. Reactionary hemorrhage and wound breakdown can easily follow over-vigorous active exercises or rough handling of the stump.

With this routine the patient will gradually regain a measure of confidence and realize that his stump is under his active control and is not just a useless appendage. By the time the stitches are removed, about the tenth day, and the patient is about to leave his bed, full movement of the proximal joint should be possible, be it retained or regained. In addition these gentle active exercises, by stimulation of the new anastomotic circulation of the stump have set in motion
Patient erect with an ideal stump in total equilibrium.
medium) have high insertions on the femur and are thus unaffected by amputation through the femoral shaft. On the other hand, the hip extensors (gluteus maximus) and the adductor magnus have much lower insertions into the femur, and mid-femoral amputation therefore reduces their volume and power. The hip flexor, having enjoyed an immunity from surgery, is the real villain of the piece, and aided and abetted by a sagging bed or the improper use of sandbags and pillows placed under the stump during the early post-operative days, exploits its advantage of power preponderance and pulls the stump into a position of flexion contracture. The fibres of the weakened extensor muscle are stretched and remain stretched, thus aggravating the power loss and inability to recover the normal hip extension position.

From the practical angle, inability to extend a thigh stump to the neutral dependent position is the greatest obstacle to the resumption of easy, comfortable ambulation. If the stump assumes a position of rest in flexion and only by extreme lordosis can be extended fully, it follows that the range of hip-joint movement becomes severely restricted and gait with an artificial limb is considerably diminished, with little hope of recovering the full natural pace (Plates XIII, XIV and XV).

To a lesser degree the abductors overpower the adductors, and the stump becomes not only flexed but also abducted. If opposing flexor-extensor, or abductor-adductor muscles, are not in tonal equilibrium at rest the stump position will be a deviation from the normal by over-action of the stronger group. For a patient to have an above-knee stump of appropriate length and good contour with no oedema; which is well nourished by competent circulation with a linear, non-adherent featureless and consolidated scar; which has no redundant terminal soft tissue in the form of skin flaps and yet to be severely handicapped by the malposition of flexion and inability to extend at the hip joint, is indeed a great misfortune. Exercises are therefore designed, apart from strengthening the stump muscles, to preserve the full range of hip extension movement.
the process of stump shrinkage by reduction of terminal oedema.

Individual stumps may now be considered independently, but a few words of explanation on the predetermined length of stumps may be of interest.

Two important factors predominate.

Muscular. There should be sufficient length of bone to provide adequate insertion of opposing muscle groups so that the resultant position of the stump at rest is one of static equilibrium in the normal relative position of the natural limb. With this consideration, is associated a sufficiency of muscle tissue needed to activate, with positive control, an appropriate artificial limb.

Circulatory. The other governing factor is the future competency of the new stump-end circulation. By reason of vascular deficiency and coincident nutritional impairment the ends of unduly long stumps often tend to break down with advancing years and re-amputation may become necessary. It often happens that trauma and disease prevent the surgeon from obtaining an ideal length of stump, but the retention of a fully functioning knee and elbow joint always outweighs the disadvantages of a stump shorter than the ideal length.

Stumps are measured as follows:

<table>
<thead>
<tr>
<th>Location</th>
<th>Measurement</th>
<th>Ideal Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Elbow</td>
<td>Tip of acromion process to end of bone</td>
<td>8 in.</td>
</tr>
<tr>
<td>Below Elbow</td>
<td>Tip of olecranon process to end of bone</td>
<td>7 in.</td>
</tr>
<tr>
<td>Above Knee</td>
<td>Tip of great trochanter to end of bone</td>
<td>10-11 in.</td>
</tr>
<tr>
<td>Below Knee</td>
<td>Joint margin of tibial head to end of bone</td>
<td>5 in.</td>
</tr>
</tbody>
</table>

Above-Knee Stump

A brief reference to lower extremity anatomy readily explains why stump exercises are necessary to retain or obtain a normally positioned stump and thereby prevent or correct deviations and contractures commonly known as “stump deformities”. The flexors (iliopsoas) and abductors (gluteus
a sling suitable for winding round the stump in a figure-of-eight. The extensors of the thigh are exercised first, using a light poundage spring which will be sufficient to counterbalance the weight of the stump and to give only mild resistance. The stump should be lifted into slight flexion by the fixation (Fig. 103A) to call into play the stretch reflex in the weak extensor group. The physiotherapist first assists extension by handling the sling, not the stump, against the spring, while active flexion which is not required is avoided as the spring lifts the stump passively. As the extensors work harder against increasing resistance the reciprocal relaxation of the powerful flexors will be greater.

The adductor group is exercised in a similar manner with the patient lying on the sound side.

*Resistance exercises in the department.* The patient may now sit on a table or high stool and the spring unit is attached to a point in front for extension and at the side for adduction (Fig. 104B). Note that the sling now requires a light strap to fasten it to a waist band so that it does not slip off.

Alternatively a pulley and weight circuit may be used with weights progressing from 2 to 14 lb. If desired, the patient
Above-Knee Stump Exercises

In bed—24 hours to 10 days. As already mentioned gentle, free, active stump exercises are started within the first 48 hours. The patient is instructed to move the stump through a small range primarily practising extension and adduction. It is not necessary for the patient to remain supine; in fact exercises in lateral and prone positions add to his confidence and comfort. In the prone position the patient is instructed to clasp his hands behind his back and arch vigorously several times. This should be done twice a day, gradually increasing the duration and vigour of the exercise. He is then instructed to brace the stump backwards and inwards at the same time.

In the early days, mechanical aids to assist or resist are not indicated because externally applied force may prejudice the stump-healing process. It is sometimes overlooked that amputation of a limb is a major operation, involving considerable tissue disturbance. There is a large operation wound which can easily be pulled open in the early days, or after healing the firm linear scar may be stretched to thin, friable, tissue-paper thickness which is readily vulnerable to the slightest frictional trauma. A safe plan is to defer apparatus exercises until the stitches have been removed 10 to 12 days, unless the stump is short and flexion is obvious, when with the utmost caution a resistance of 2 to 4 lb. only may be used. The general rule that exercises should never exceed the patient’s comfort is rigorously applied.

Stump pain and tenderness precludes all forms of stump exercise.

Exercises out of bed. Once the stitches have been removed and the stump permits gentle handling, cotton wool padding is no longer necessary. A thin piece of gauze is strapped over the consolidating scar and 6-in. bandages are applied to the stump and hip (see pp. 187-190). Mechanical aids designed either to resist muscle work or assist movement may be used when treating the stump.

Resistance exercises in bed. A long spring unit is used with
in duration and frequency during the subsequent 8 or 9 days until the stitches are removed.

During this period hip-joint movements are simultaneously performed as full control, particularly of extension, is an equally important prerequisite to successful wearing of a

![Diagram](image)

**Fig. 104.** (A) Assisted adduction. (B) Resisted adduction. (C) Assisted extension. (D) Resisted extension.
may stand erect for these exercises with suitable hand support.

Flexion and Abduction are Never Practised.

If the patient has a flexion-abduction deformity, then it is advisable in some cases first to assist the desired movement. For example, the patient in Figs. 104, a and c, is gaining assistance from the weight to produce the difficult movement. He must be instructed at the same time to attempt to extend, or adduct as the case may be, so that a passive stretch is imposed on a physiological lengthening. As soon as some movement in the required direction has been gained then the patient turns round and works against resistance (Figs. 104, b and d).

The exercises should be done under supervision in a physiotherapy department at least twice a day. If possible, the patients should be grouped together with the result that they become less introspective and competition with their fellows stimulates greater efforts. The caution that exercises must not cause fatigue or stump pain, still operates. Apart from strengthening the stump muscles these exercises serve the purpose of re-educating the patient in stump muscle control. A powerful stump is of no use in the activation of an artificial limb unless it can function with precision and speed in obedience to brain direction or ambulatory reflex.

Below-Knee Stump

The ideal site of amputation of a below-knee stump is so placed that there is no interference with the flexor and extensor muscles acting over the knee joint. In spite of this the quadriceps lose tone, especially the vastus medialis, whilst the hamstrings tend to overact and pull the stump into flexion. For the first two days after amputation a long back splint is bandaged to the posterior surface of the thigh and stump, and if there are no contra-indications of pain or hemorrhage the back splint, but not the stump dressing, is removed within 48 hours. Gentle free flexion and extension exercises of the knee joint are started gradually, increasing
tional or "other" leg complications, the patient is able to stand in normal erect posture on the sound leg in ease, and confidence, and the amputation stump should fall by gravity in the normal anatomical position of the natural limb. There should be no extensor muscle effort required to retain the stump in that position.

![Diagram of resisted extension for below-knee stump](image)

**Fig. 103.** Resisted extension for below-knee stump. Note the well-padded sling.

**Arm Stumps**

In contrast to the lower extremity the upper extremity has a wide range of action and maximum emphasis is therefore directed to the maintenance of full shoulder joint movement and full tone of the shoulder girdle muscles. Gentle exercises should be started 24 hours after operation, gradually increasing in duration, frequency and range concurrent with general constitutional recovery. In below elbow cases, the elbow joint is exercised simultaneously with the shoulder joint.

A stiff shoulder or one of limited movement in an arm amputee is indeed a tragedy, and apart from the functional power loss due to restricted artificial arm usage, the patient is apt to become disconsolate, and concentrate entirely on the sound arm. In fact he becomes "one-arm" minded, and the
below-knee artificial limb. The amputated limb should lie flat on the bed by its own weight without pillows or sandbags in support, and further splinting or other restraint is not necessary unless the patient is unco-operative and full knee-joint extension is not being maintained. Resistance exercises are not advocated until the stitches are removed.

When out of bed and with the wound soundly healed more vigorous exercises are initiated. They are a combination of quadriceps drill, spring resistance or weight and pulley exercises of a similar nature to those already described for above-knee stumps. The same principles of gradual increase in strength and frequency apply. A strong word of warning is necessary when mechanically resisted exercises are given to a below-knee stump. In the above-knee stump the femoral shaft is surrounded and well cushioned by thick layers of muscle, and the weight-bearing surface of the future prosthesis is the ischial tuberosity. The sling may be safely applied direct to the skin of the stump. In the below-knee stump bony landmarks predominate; in particular the anterior tibial crest and the fibular head with the lateral popliteal nerve just below. There is minimal subcutaneous tissue between skin and bone in these areas, and the skin is more susceptible to nutritional failure than in the more fleshy parts of the stump. Sound healing of skin abrasions over the anterior tibial crest is notoriously slow, and as this is a weight-bearing and forward propulsion area for the below-knee artificial limb, the limb fitting is necessarily deferred and the patient condemned to crutches for weeks or months simply by reason of a small abrasion which anywhere else would be almost negligible. Every precaution should be taken to avoid such bone pressure point abrasions by adequate padding beneath the sling (Fig. 105). Should knee flexion contracture with loss of full extension be present, "assisted" extensor exercises are to be considered. The sling pulls on the posterior surface of the stump and assisted by the simultaneous active contractions of the quadriceps overcomes the shortened flexors. The net result of these efforts should be that within 3 weeks of amputation, and provided there are no untoward constitu-
thus more vulnerable as a cause of future stump pain and painful phantom arm. It is impossible to be too gentle when handling a recent arm amputation stump.

Reduction of Post-operative Öedema by Stump Bandaging

Following the major operation of amputation, which necessitates complete division of all arteries, nerves and lymphatics, a new blood vessel and lymphatic circulatory system must be established in the lower half of the stump. This derangement of blood circulation results in a considerable exudate of fluid into the tissues, but as the lymphatics have also been damaged, absorption of excess tissue fluid into the operation area is impeded and swelling of the stump from acute and then subacute òedema results. Unfortunately the condition is cumulative, the more exudate the less absorption, and the relaxed atonic stump musculature adds to the difficulties.

Unless active support by stump bandaging is instituted, the stump, particularly in the dependent position when the patient is out of bed, becomes heavy due to the òedema becoming “solid”. This implies a change from the early reactionary post-operative “puffy” òedema to a heavy “pudding” type, uncomfortable mass. An òedematous arm or leg stump cannot be fitted with an artificial limb because exercises and bandaging not only cause shrinkage of circumferential stump measurements by absorption of òedema but also alter the contour of the stump. An artificial limb socket made to the measurements of an òedematous stump would very quickly become too large and is thus economically impracticable and wastes much valuable time.

Every amputation stump eventually assumes a final static contour, but only when all òedema has disappeared and muscle development is stabilized. Dimensional stump changes do, however, occur in accordance with general loss or increase of body weight and also with discontinuance of artificial limb wearing when the stump becomes atonic and flabby.

The answer to the problem of òedema is systematic
amputation stump remains little more than a useless appendage, more of a hindrance than a help. The manual worker amputee, depending for his livelihood on the motor prehensile function of both hands and arms demands special attention.

It is a well-known fact that the loss of an arm is a much greater shock to the patient than the loss of a leg. Nowadays, especially in industrial areas, upper extremity amputation for trauma is a not infrequent casualty, and it is, in fact, the commonest reason for arm amputation. On the other hand very few arms are lost as a result of disease.

The function of the hand is to hold and to feel, based primarily on the necessity for man to feed himself and thereby sustain life. The motor function of grip may need to be of coarse, medium or precision dimension, and rehabilitation of an arm amputee is directed to the restoration of this faculty. Sensory loss cannot be restored.

If maximum value is to be derived from an artificial arm, full use of the musculature of both shoulder girdles and a full range of shoulder movement is essential. For this reason there should be no delay in starting treatment, and the patient's interest and will to recover must not be allowed to stagnate. Once the shoulder is allowed to become fixed the recovery of full joint movement in a short above-elbow stump is an almost impossible task, and equally difficult is the restoration of an arm amputee's lost enthusiasm.

The most effective stimulus is for the patient to attend as early as possible at Ministry of Health Artificial Limb Centre Arm Training School. He will see the progress and achievement of other patients equally, and perhaps more, disabled and will readily realize the future value and use of his amputation stump and his shoulder muscles. Unless there has been direct damage to the joint or brachial plexus, full range of shoulder movement should be possible when the stitches are removed on the tenth day. As with leg exercises, by restoring stump and circulation, full free arm movements are a potent factor in the reduction of post-operative oedema. A word of caution. The nerve endings of the upper extremity are more susceptible to painful stimulation and
point and thence high up on the outer side to the buttock level. It is passed around the pelvis and back on to the stump making a spica turn. Care should be taken to ensure that the cross-over of the bandage is lateral and not anterior. From here the stump is again bandaged using tension at the extremity, the turns proceeding proximally and is then finished off. As the bandaging proceeds higher up the stump so the tension should be diminished.

The importance of carrying the bandage high into the perineum is to avoid a roll of flesh appearing between it and the upper edge of the bandage. Every care should be taken to avoid the hip spica being incorrectly applied and pulling the stump into flexion. The spica crossing should be on the lateral not the anterior aspect of the hip.

Fig. 106. The contours of well and badly bandaged stumps.
(A) After operation. Darkened areas show desired shrinkage. (B) Lines of pull of bandage. (C) Final stabilized contour. (D) How not to bandage. (E) Result of circular bandage.
bandaging but to be effective, the bandage must be properly applied. The following rules are observed for all stump bandages.

Bandaging is begun when the stitches, operation dressings and cotton wool padding are removed. A well-applied bandage, apart from making the patient comfortable, allows him to be freely mobile without risk of further gravitational oedema.

If gradual progressive reduction in stump oedema is to be achieved, bandage tension must remain constant. To this end the bandage is applied direct to the stump without padding four times daily. Except for the purpose of free exercise and re-application, bandages on arm and leg stumps must be worn continuously day and night.

The layers of the bandage should be absolutely flat on the skin with even distribution of pressure and without any tendency for the edges to dig in to the soft tissues. Diminishing tension is always used as the bandage proceeds proximally and turns are applied obliquely and _ater in a circular manner (Fig. 106).

**Above-knee stump.** Two or more 6-in.-wide crepe bandages stitched end-to-end are used. The patient lies supine on a couch or a very firm bed with the stump in full extension and the free end of the bandage is placed upon the anterior surface of the stump at the level of the inguinal ligament, being held in that position by the patient’s thumbs. The bandage is then firmly drawn distally over the stump end and carried posteriorly to gluteal fold level, where it is held by the patient’s forefingers. It is then brought down obliquely and laterally over the stump end and up to the original anterior supporting point. Another downward loop is made, this time obliquely medially over the stump and to the posterior supporting gluteal point.

The bandage is now twisted and a turn is made around the upper aspect of the stump as high as possible into the perineum, only sufficient tension being used in this turn to secure the upper extremities of the three slings. The patient can now remove his hands. Next, the bandage is carried down to the stump’s extremity, using increasing tension at that
Below-elbow stumps. A 3-in. bandage is used and the method is similar to that for below-knee stump. The free end of the bandage is applied to the flexor surface of the stump at the bend of the elbow and retained in position by the attendant’s thumb. Three firm slings passing over the stump end are made, and these are held by a circular turn of only sufficient tension to prevent them from slipping off. Oblique layers as with below-knee stump are applied and these are extended to embrace the lower humerus for anchorage and then brought back to the stump.

There are three precautions to be observed:

1. The supracondylar turns must not constrict the circulation.
2. The olecranon area corresponding to the patella should not be covered, thus permitting flexion and extension movement when the stump is bandaged.
3. The stump must not be pulled into flexion.

Upper arm. A 3-in. bandage is used but in this case the bandaging is confined to the stump itself. Efforts to include the shoulder joint in a spica corresponding to the hip are not successful. The bandage applied is firm at the lower end of the stump with diminishing tension as the axilla is approached.

**Subsequent Treatment**

Having prepared the patient and the amputation stump, the physiotherapist may now wish to know the future procedure when the patient is referred to the Limb Fitting Centre.

The following is a brief summary:

**Lower Extremity**

1. **Hindquarter Amputations, disarticulation of hip, very short femoral stumps.**

*Prerequisites.* The wound must be healed and the patient able to stand on the natural leg with confidence.

*Action at Limb Centre.* The patient is provided with a tilting table pylon which consists of a large “Durestos” socket, made from a plaster of Paris cast of the lower trunk, attached
Errors in above-knee bandaging:
1. Using narrow bandages.
2. Failure to bring the bandage to the perineum.
3. Pulling the stump into flexion.
4. Bandaging circularly, thus causing a mid-stump constriction and a solid bulbous stump end. The lines of pull should be obliquely upwards from inner and outer stump end corners (see Fig. 106).
5. Infrequency and irregularity of application.
6. Limitation of bandaging to the stump and failure to extend it as a hip spica.

Above-knee stump bandaging is often extremely difficult especially in aged, corpulent patients, where the line of demarcation between trunk and extremity may be somewhat ill-defined, and bandaging demonstrators invariably select slim agile patients as their subjects. Nevertheless, every effort should be made, although the early use of the “Duresteo” socket walking pylon as a provisional prosthesis has been a boon and a blessing in the accelerated reduction of stump oedema. (See p. 192.)

Below-knee Stumps. The patient can be taught to bandage this stump himself. He is seated with the knee joint fully extended and one (or two) 4-in. crepe bandages are used. Starting on the anterior surface at the lower margin of the patella three firm slings as in above-knee cases are used to support the oedematous stump. The bandage is carried around the tibial head to anchor the slings and then obliquely over the stump ends, the line of pull now being upwards and inwards or upwards and outwards in order to compress and shrink the stump-end corners.

Corresponding to the spica turn around the waist the bandage is then taken twice round the lower end of the femur, just above the condyles and back to the stump again. These femoral turns are purely for anchoring the bandage and to prevent it slipping off. There must be no popliteal constriction or stump avascularity or further oedema may result. The patella and anterior aspect of the knee should be free of bandage in order to permit flexion-extension mobility.
Articulated artificial limb. The socket has been set in flexion to enable the patient to stand upright.
by a hip joint hinge to two pylon uprights which end below in a 6-in. rocker base. The pylon weighs only a few pounds and is intended only as a temporary prosthesis but it does facilitate early ambulation.

2. Mid-thigh Amputations. If uninterrupted healing has occurred the patient should be able to attend the Limb Centre within 3 to 4 weeks.

Prerequisites are:
(a) The stump wound should be firmly healed and the scar sound.
(b) He should be able to stand on the sound leg and be able to use crutches.
(c) Free stump movement should be possible.
(d) Reduction of oedema and stump shrinkage should be evident.
(e) Gentle handling of the stump should not discomfort the patient.

Note: It is not possible to take limb-fitting action if the amputation wound is not soundly healed, if the stump is still tender, or if the patient cannot stand on the remaining leg.

Action at Limb Centre. In order to expedite ambulation and independent mobility, all primary above-knee amputees are supplied with a walking pylon as a temporary prosthesis. This consists of a "Durestos" socket fitting the stump from actual measurement. The socket is supported by the two side uprights which end below in a 6-in. rocker base. The pylon is suspended from the pelvis by a simple pelvic band and lap-type hip joint (Plate XVI).

Under close supervision the patients are taught to balance and develop a sense of confidence and security so that within a few days independence is achieved. Stump exercises and bandaging are generally not required once the patient can manage the pylon which is very light, weighing only 2 lb. and is purely for temporary use. Apart from enabling the patient to walk, the active movements strengthen the stump muscles, reduce any residual stump oedema and prepare the patient and stump for the early supply of an
Articulated artificial limb. Plaster of Paris pylons are no longer used as they were found to be unsatisfactory and too heavy.


Prerequisites. The stump wound should be firmly healed and there should be no abrasions over bony prominences.

Stump exercises and stump bandaging are more easily carried out to effective standards in a below-knee than in an above-knee stump and early supply of an artificial limb is indicated. Pylons for below-knee amputations are not advised.

Arm Amputations

The patient should be brought to the Centre within 3 weeks of amputation. For the patient's morale and general well-being an artificial arm should be supplied as quickly as possible and training in its use by a qualified instructor is a paramount essential.

Conclusion

If the leg amputee can walk again with a near to natural, easy swinging, full length follow-through gait in comfort and with security; if the arm amputee can resume former employment, or one approaching it, or be trained in one equally useful and remunerative; if both can enjoy the same amenities of life as before the loss of their limbs, the physiotherapist can rightly claim a large share of "object achieved".
A temporary prosthesis: left, front view; right, side view, for an above-knee stump.

Note—Pelvic band, hip joint, "Durestol" socket made to actual measurements, and the rocker base.
more, it is amazing how such people can keep going. The elderly can maintain independence provided they make no sudden effort and adhere to a simple routine of limited, unhurried activity. Once this is disrupted they find it difficult to regain the habits of former activity. Following illness, the more physical comforts they have the lower the standard of recovery needed to reach independence.

At one extreme the patient is still fully active, well able to look after herself, helping others where possible; her mental faculties have increased with experience and the mellowing of age. She is mentally and physically younger than her age group and will gladly accept treatment and respond quickly. At the other extreme is the lonely, old person, possibly in poor social circumstances, who is trying to manage alone. Some chronic condition such as arthritis or a failing heart may narrow her sphere of activity and she is liable to become poorly nourished and dependent on others. Finally some comparatively trivial cause can produce a complete breakdown leading to incapacity and admission to hospital.

The general aim of treatment is similar for young and geriatric patients, from the stage of bed to chair to walking, they are aided back to former activity. The elderly patient will pass through the stages at a much slower speed and may never reach her former standard. Unless the patient is completely helpless some degree of independence must be maintained to minimize the misery of complete dependence.

The General Approach and Timing of Treatment for the Geriatric Patient

Early sympathetic treatment is imperative before the patient has lost hope and reached the stage of pathetic apathy. Time for recovery must be given and treatment must be sufficiently prolonged. All the team will help her to accommodate to the shock of leaving home, being in new surroundings and facing the disruption of her normal routine. It is obvious by results that some are more naturally gifted in dealing with the aged and are able to sense the subtle differences frequently needed.
CHAPTER 17

Suspension Therapy and the Geriatric Patient

BY MRS. P. SAVIN, M.C.S.P.

The term geriatric, derived from the Greek word "geros" for old age, is used to describe the patient of pensionable age. An increasing number of geriatric patients are now receiving active treatment in hospitals and special rehabilitation units. Probably because men are usually "looked after", women predominate in this group, so in the text the feminine pronoun is used. Previously these patients received only medical and nursing care but now they have the benefit of a treatment team which includes doctors, nurses, physiotherapists, occupational therapists, almoners and allied social workers.

A general and wide scheme of activity is planned for each patient in which, at various stages, the activities of the different members of the team predominate. Each patient has her own "Recovery Age", which may be below or above her actual number of years. The capacity for recovery may be there, but the degree of recovery will depend on the correct assessment of expected activity and the application of adequate treatment. Treatment will differ from that of the young in general approach and timing.

A young person with a healthy constitution and hope of a full life stretching ahead will, if ill, expect the return of full mobility, muscle power, perfect co-ordination of movement and endurance for her particular way of life. She has every incentive to recover and has all the resources of a young physique to aid her. In general she will respond to vigorous treatment and will pass quickly through the stages of recovery with only a comparatively short stay in bed.

Elderly people nearing the end of life vary in their ability to recover. Although the body has been in use for 60 years or
more, it is amazing how such people can keep going. The elderly can maintain independence provided they make no sudden effort and adhere to a simple routine of limited, unhurried activity. Once this is disrupted they find it difficult to regain the habits of former activity. Following illness, the more physical comforts they have the lower the standard of recovery needed to reach independence.

At one extreme the patient is still fully active, well able to look after herself, helping others where possible; her mental faculties have increased with experience and the mellowing of age. She is mentally and physically younger than her age group and will gladly accept treatment and respond quickly. At the other extreme is the lonely, old person, possibly in poor social circumstances, who is trying to manage alone. Some chronic condition such as arthritis or a failing heart may narrow her sphere of activity and she is liable to become poorly nourished and dependent on others. Finally some comparatively trivial cause can produce a complete breakdown leading to incapacity and admission to hospital.

The general aim of treatment is similar for young and geriatric patients, from the stage of bed to chair to walking, they are aided back to former activity. The elderly patient will pass through the stages at a much slower speed and may never reach her former standard. Unless the patient is completely helpless some degree of independence must be maintained to minimize the misery of complete dependence.

The General Approach and Timing of Treatment for the Geriatric Patient

Early sympathetic treatment is imperative before the patient has lost hope and reached the stage of pathetic apathy. Time for recovery must be given and treatment must be sufficiently prolonged. All the team will help her to accommodate to the shock of leaving home, being in new surroundings and facing the disruption of her normal routine. It is obvious by results that some are more naturally gifted in dealing with the aged and are able to sense the subtle differences frequently needed
CHAPTER 17

Suspension Therapy and the Geriatric Patient

BY MRS P. BAVIN, M.O.S.P.

The term geriatric, derived from the Greek word "geros" for old age, is used to describe the patient of pensionable age. An increasing number of geriatric patients are now receiving active treatment in hospitals and special rehabilitation units. Probably because men are usually "looked after", women predominate in this group, so in the text the feminine pronoun is used. Previously these patients received only medical and nursing care but now they have the benefit of a treatment team which includes doctors, nurses, physiotherapists, occupational therapists, almoners and allied social workers.

A general and wide scheme of activity is planned for each patient in which, at various stages, the activities of the different members of the team predominate. Each patient has her own "Recovery Age", which may be below or above her actual number of years. The capacity for recovery may be there, but the degree of recovery will depend on the correct assessment of expected activity and the application of adequate treatment. Treatment will differ from that of the young in general approach and timing.

A young person with a healthy constitution and hope of a full life stretching ahead will, if ill, expect the return of full mobility, muscle power, perfect co-ordination of movement and endurance for her particular way of life. She has every incentive to recover and has all the resources of a young physique to aid her. In general she will respond to vigorous treatment and will pass quickly through the stages of recovery with only a comparatively short stay in bed.

Elderly people nearing the end of life vary in their ability to recover. Although the body has been in use for 60 years or
Signs of distress are: sudden loss of concentration, change of colour—cyanosis, pallor, flushing—or failure to respond to a command.

When something new is added even though little effort appears to be involved, it should only be done once or twice, the next day the patient will be used to the progression and ready for more.

To establish the pattern and habit, frequent repetition of movement is necessary and the geriatric patient does not find this boring as would a younger person. Treatment sessions are prolonged so that there is time for movement and frequent rests. Progression is slower and each step is finely graded so that the patient does not lose confidence in her own capacity. By this approach her confidence will be gained and she will often show a hidden capacity which would otherwise have lain dormant. She must always be given praise for any effort made.

The patient's interest may be maintained by altering her surroundings. For example, she may change from individual to group treatment in the ward, then in the department, or join a mixed group which includes male patients. Class work is a tremendous stimulus because of the competitive spirit induced, and can be done to music. Old time tunes are popular, using quick rhythms for hand and arm, slow rhythms for leg and waltzes for trunk movements. The efforts to maintain interest in the winter months may be supplemented in good weather by visits to the garden and the company of outside friends. The ideal is to alternate the various ways of keeping the patient active.

Treatment will consist of local treatment for the condition together with a general activity scheme. The physiotherapist will give local treatment for the patient's primary condition by whatever method required. She will also play her part in the general activity scheme by planning the definite exercise sessions in bed or in the department to maintain and re-train the movements and functions. In this scheme suspension therapy and the use of the Guthrie Smith Bedchair can often play a useful part in the rehabilitation of the geriatric patient.
in timing and approach at each stage. In the past, assessment of the recovery standard was left for too long and no link was made between physical and social states. Now all members of the team assist in maintaining this link. Frequent review is necessary so that all the team are aware of the level of the final standard and aim. Too low an estimate may cause curtailment of treatment; too high an estimate may prolong the hospitalization by expecting a finesse of movement which is unnecessary. Specialized treatment should be stopped when a useful standard of recovery has been reached, but improvement will often follow over a long period, especially when the patient is back to a normal routine in which she must make the effort to look after herself.

General Care of the Patient

General nursing will be greatly facilitated if the patient can move easily and remain continent and if she can perform the personal tasks of feeding and toilet. The appearance of contractures is often insidious and they are sometimes not recognized until well established, but the physiotherapist with her knowledge of body mechanics, plays a major role in their prevention. Once the patient can be helped into the upright position, if necessary with support, she will have the advantage of the stimulating effects produced by such variation of posture. The change may often produce an amazing transformation in a patient who seemed quite helpless in the lying position. She may now attempt to move her limbs and trunk and may even be able to propel herself in a suitable chair.

Physotherapy. When the patient is ordered special help from the physiotherapist the movements encouraged first are those which have been automatic throughout life. The patient will find her own rhythm for performing these reflex patterns of movement and must not be hurried beyond her capacity. Since the patient has little reserve, fatigue should never be permitted and she should finish the treatment stimulated and feeling that she could attempt more.
with chain and handle is not suitable since its position cannot be varied and it is not at the right angle when the patient is sitting upright. A series of hand grips should be attached to the overhead and lateral bars of the frame to allow for assistance to movement up and down the bed and in and out of chairs. The hand grips may be softened by padding or by making them of latex foam.

6. All the apparatus needed can be hung and transported on a tubular frame on wheels. This will carry spare ropes, springs, hooks, slings, etc. (Plate XVIII).

7. For assistance in weight bearing and walking an overhead track is useful.

APPLICATION. Pressure can be relieved from such areas as heels, buttocks, elbows by suspending the patient in the special latex slings. If the legs are suspended, care should be taken not to lift them too high thus tilting the pelvis so that the patient's weight rests on the sacrum.

Stockinette is tied to form a sling and is attached direct to the cord. This method avoids any cutting edge and suits the most tender skins. It is particularly suitable for suspending sore heels when a double support can be given under the sole of the foot and calf and under the thigh, the heel being left clear. It may be found more convenient to attach the foot support separately by tying the stockinette over the dorsum, to prevent slipping and suspending it by a cord to a 1-lb. weight passing over a pulley attached to the overhead frame. This will allow free foot movement while the calf and thigh slings are fixed direct to the frame by cords or by cords with springs inserted (Fig. 107).

A similar method may be used to support the head to prevent it from falling sideways or subluxating forwards with
Suspension therapy is useful for the geriatric patient because it encourages repetitive movements for prolonged periods and treatment can be given in groups. It may also be used for local treatment to relieve pressure, to prevent contractions and to encourage movement within the general activity scheme. Either temporary or permanent suspension may be employed.

Apparatus

1. For multi-point fixation an overhead frame of tubular steel with at least two movable cross bars will be required. Clearance should be about 4 ft. 6 in. from the bed.

2. For arm treatments two uprights fixed to the head of the bed with three horizontal bars attached at right angles as shown in Plate XVII will be sufficient.

3. A stock of springs each marked with a painted label for quick recognition of size will also be required. Spring clips should be attached to either end of each spring.

4. A stock of ropes, blind cord, cleats, rings, hooks, slings, special slings to avoid pressure, three-ring slings, webbing, weights and pulleys should be available. In some cases cord, because it is less cumbersome, slides more freely and is more readily adjusted, is better than rope. Small cleats must be made to fit the cord. If sufficient stock is available, circuits can be made up in a few minutes to the exact length required. Slings can be made of sail cloth or latex foam supported in stockinette. The latex foam is usually \( \frac{1}{4}\) in. thick, of medium density and is placed inside the tubular stockinette. The weighted bags should be filled with sand or shot, marked according to size and graded in \( \frac{1}{4}\) lb. up to a maximum of 5 lb. The pulleys should be small for attachment to the overhead frame for self-assisted pulley work, or for obtaining counterbalance.

5. Hand grips must be suspended at just the right height and angle to give patients, particularly those with stiff shoulders, the correct leverage. The normal Pearson pulley
the chin pressing onto the sternum. This has been found useful in advanced cases of paralysis agitans and in rheumatoid arthritis when deformity is already present (Figs. 108a and b).

**Contractures.** Spring suspension of the legs for long periods or as a permanent measure is particularly effective in regaining knee extension following adaptive shortening of structures on the posterior aspect of the knee. The leg is supported under the calf and foot so that the weight of the limb will stretch the shortened structures (Plate XIX). The

![Image](image.png)

Fig. 108. (A) and (B) Latex-foam slings supporting the head, which is counterbalanced to correct deformity.

patient is encouraged to perform active extension. This treatment is often used to give a preliminary stretch prior to the application of turnbuckles which may be needed to produce the final degree of movement.

For general activity, Suspension therapy is applied to maintain mobility and prevent contractures while in bed and to regain mobility following long immobilization. The arms and legs are suspended by axial fixation, springs of sufficient tension to counterbalance the weight of the limbs being inserted in each unit. The patient is taught to perform small repetitive movements, and since the limbs are supported they are free to move without having to overcome the friction of the bedclothes. The sense of buoyancy and the
Spring suspension to allow exercise and giving crossed traction to extend the knees.
The tubular steel frame for transporting equipment.
recoil of the spring produced by the slightest movement will encourage constant attempts to move the arms from the sides, to bend and stretch the elbows and to extend the hips and knees. The patient can push as gently or as hard as she likes and the spring will only give resistance equal to her effort. She can make her own progression using the same spring, so no intricate grading is needed. The trunk may also be supported for activity periods throughout the day. When other treatments are not in progress, trunk or limbs may be permanently suspended.

Prolonged treatment sessions. The elderly patient benefits from a long treatment session of 1 to 1½ hours which will allow for frequent rests, slow expenditure of energy and movement of different parts of the body.

Group suspension. In hospital it is often desirable to arrange group suspension therapy for bed patients if it is not convenient to transport them to the department. It is a great encouragement to the elderly patient to see others performing similar movements at the same time. This method does not necessarily increase the number of patients receiving treatment but will increase the total length of time during which each patient will be under supervision.

Grouping of conditions. In order to facilitate a routine, patients requiring similar treatment can be grouped together. For example—hip fractures and hemiplegics will both require similar apparatus for their exercises. Rheumatic cases may obtain better encouragement if placed apart from their fellow sufferers.

Establishment of ward routine. If these treatments are given in the ward, all the staff and patients will see the activity. This will make it easier to establish a routine method for using the apparatus in which nurses and physiotherapists co-operate and the presence of the apparatus does not constitute an unusual feature in the ward.

Weight-bearing training. When the stage of weight-bearing and walking has been reached, the mobile support provided by an overhead track can be of great assistance. A very heavy patient can be hoisted from a bed or chair with minimal effort and can be supported in standing by using
Patient with corset and sailcloth boots to support the feet, walking with minimum weight bearing and helped by a walking chair.
1. An adjustable thigh belt for movement.
2. A foot-rest.
3. A bed table.
4. Carrying supports for seat and legs.

It is important to understand the principles of its application prior to use and for the operator to try it on herself and so feel the support and movement possible.

**Application**

1. **FOR THE COMFORT, SECURITY AND MAINTENANCE OF GOOD POSTURE OF THE PATIENT.** It can be used as a simple bed rest without any of the additional attachments, and should rest against the head of the bed. The back is shaped to provide a basis for the pillows to support the natural curves of the spine in the upright position.

   The side pieces give a sense of security and something to grasp or to lean against, and encourage the patient to move away from the pillows. The patient may grasp the side pieces when lifting the pelvis for changing her position or during the insertion of a bed-pan. When the thigh belt and a foot support are added, the body is stabilized and the usual tendency to slip down the bed is resisted.

   If the bed table is slotted into the hand grips, it can be used as a tray for meals, or for books, or as a support when leaning forwards for a change of position.

2. **AS A NURSING AID. A LEVER.** When the chair is placed further down the bed, and a thigh strap is added, the chair can act as a lever for tilting the more helpless patient backwards to insert ring or bed-pan, or for turning the patient on to the side during nursing procedures such as care of the pressure points. She can be rotated round to remain in a sitting position over the side of the bed avoiding the effort involved in lifting her out into a chair. This is useful if the patient is heavy or can remain in the sitting position only for short periods. The foot-rest or some other form of foot support will be needed if the patient is in a high bed. (Plate XXII A to D).

   This is a practical application of the first order of levers, the rim of the chair acting as the fulcrum, and it may often
Fig. 110. The chair used as a means of exercise.

(A) The starting position.
(B) Sitting forward.
(C) Full contraction of the extensor muscles.
(D) Trunk turning.
prevent the jarring and handling involved in movement, especially if the joints are painful. The thigh belt consists of a canvas belt passing under the thighs which is attached to the sides of the chair by straps and buckles. The belt is thickly padded by 2-in. latex foam rubber to prevent undue pressure under the thighs and is covered by washable material. A piece of 6-in.-wide plaster stockinette proves a simple covering which may be conveniently changed. The belt must lie at a point about 1 in. proximal to the knee joints, and will require an adjustment in tension for every length of thigh. It tilts the patient on to her "seat", just flexing the knees, thus creating a balance of body weight which allows the trunk to move to-and-fro in a rocking motion. The foot-rest consists of a foot support on rockers. It can be attached to the side pieces of a chair by straps and is adjusted or removed by its quick-release buckles.

A carrying chair. The chair can be used by two assistants as a carrying chair if a seat belt as well as a thigh belt are inserted. If the legs need support, extension rods are slipped into the side pieces, to which slings are attached to pass under the knees and ankles (Plate XXIB).

Activity aid. In bed. The chair also becomes a rocking device to allow exercise of neck, trunk and legs and feet. It is first placed well down the bed to allow movement. The foot-rest and a well-padded thigh belt are inserted. The patient can sit forward in bed, turn her trunk or tilt back and fully contract all the extensor muscles (Figs. 110A to D).

The foot-rest may be used in bed for exercising the feet, for toe movements, arch formation or for dorsi- or plantar flexion exercises. Pressure stimuli from the soles of the feet are maintained against the foot-rest, using the extensor muscles as in standing.

As a chair. When sitting on the side of the bed with the thigh strap in place the patient can continue to practise trunk movements in the chair and also non-weight-bearing leg extension and flexion exercises. In this position the straps of the foot-rest may be shortened so that it can be used for support, or as a slight resistance when practising knee extension.
The case with painful shoulders either from acute symptoms or when permanent changes have occurred greatly appreciates being turned on to the side, or carried in the chair, rather than being lifted by the arms.

5. Osteo-arthritis. Severely affected cases with fixed hips can use the rocking movements in bed to mobilize the lumbar spine. They can progress to a sitting position on the side of the bed when previously they may have found it impossible to sit in an ordinary chair, and may then progress direct to standing.

6. The heart case. In bed. With the bed-table in position the patient can lean forward on the pillows if in respiratory distress.

As a chair. A case of congestive failure can be swung round to the side of the bed and can lean forward there with the legs dependent thus allowing gravity to relieve the central congestion.

Graded exercise can be begun after prolonged rest by gentle exercises in the chair.

7. Respiratory conditions. The chair can be used in the same way for bronchitic and asthmatic patients.

8. Abdominal surgery. By using the chair, static patients may be encouraged to sit up and move in the early post-operative stages.

Those working in a geriatric unit will be aided in their task of steering the patients towards fuller activity and enjoyment of life if these simple mechanical devices, suspension and the bed-chair, are included in the equipment.
For standing. The patient can use the chair for changing from the sitting position to standing from the side of the bed. It acts as an excellent back support which will prevent the tendency for the weaker patient to tip backwards across the bed. A timorous or weak patient in the earlier stages of re-education may be assisted from bed to the upright position with little effort. In the chair the patient is under the control of the operator who can rotate her round to the side of the bed, where she may practise balance in sitting as a preliminary to standing and walking.

In pivoting round, the patient's legs must be supported and the chair tilted well back to allow rotation on its rim, avoiding any friction on the buttocks.

Application to some Specific Conditions

1. The geriatric or any long-term patient. The chair is particularly useful for the patient who is likely to spend a long time in bed, either as a simple bed rest or applied for short periods for exercise. These patients can perform repetitive movements of back and leg extension in their own time, or sit over the side of the bed with the legs dependent for non-weight-bearing knee and foot exercises prior to standing.

2. Fracture cases. Elderly patients with fractures of the upper end of the femur nailed and plated can be encouraged to move and to sit in a chair by using the Guthrie Smith Bedchair for the first day or two until they have regained confidence.

3. The hemiplegic patient. To control posture. If it is used as a simple bed-rest, the bedchair can be used to control the position of the hemiplegic patient who lolls sideways, if necessary by inserting an extra pillow on the affected side of the trunk. The side piece is used as a basis for pillows to support the affected shoulder in some abduction, and to prevent the hand from dropping down and becoming oedematous. The patient can pull on the side rail with her unaffected arm to sit forwards.

4. Rheumatoid arthritis (acute or chronic). The chair can be used to encourage an upright posture with abduction of the arms.
limbs simultaneously in a natural manner with opportunities for bilateral movement to assess ability and compare it.

**Relaxation**

The technique of obtaining relaxation in suspension has been described in Chapter 11, and this method may be used for the treatment of many neurological conditions and varied as follows.

*The patient's position* must be selected in accordance with the state. For example, lying **...** was suitable especially where intermittent flexor spasms occur. Sidelying would then be the position of choice, with the legs suspended together and the arms suspended separately anterior to the trunk. The flexor spasms can now arise without loss of suspension (Fig. 111).

Still other patients relax more easily when movements of the opposite arm and leg can be attempted. In these cases with the patient in side lying, one leg is suspended anterior to the other and the ropes suspending the arms are arranged

*Fig. 111. The technique of suspension for flexor spasms or to train walking patterns of limb movements.*
Suspension Therapy for some Disorders of the Nervous System

BY MRS. M. HOLLIS, M.C.S.P.
AND MRS. H. A. ROGER, M.C.S.P.

Patients suffering from many of the nervous disorders are often aided in their adjustment to their disability by the use of suspension. Where inco-ordination of movement creates special difficulty due either to spasticity, weakness, ataxia, rigidity, or to unwanted movement, treatment is directed to alleviation of the symptoms.

If all these cases are to benefit by suspension—what then is the common approach?

First, suspension offers a means of complete and comfortable support. The patient can see it, if not feel it, and with experience his confidence in suspension grows. This leads first to relaxation, second to the opportunity to gain concentration on specific actions and third to movement which is easy and by this means encouraging to the discouraged. The patient who has suffered acute cerebral catastrophe or felt his limbs growing heavier and more difficult to move as his condition deteriorates, is immensely cheered when an apparently immovable limb is gently swung by the physiotherapist; he feels that if movement is there then life is not lost.

Second, suspension offers a means whereby the heaviest and most inert patient may be moved easily so that joint range may be maintained and pressure taken temporarily off the parts liable to pressure sores.

Third, it lessens static fixator muscle work and so facilitates co-ordination of movement.

Fourth, it affords facilities for movement of two or more
Suspension Therapy for Some Nervous Disorders

Positive relaxation should be taught and the patient instructed to "feel" the support of the slings. This ensures that full use is being made of the support and even that static contractions may occur. The patient is made aware first of the support and then goes on to try to contract by pressing against it. He is thus probably contracting the muscles which are opposed to those predominantly in spasm. The "over active" stronger muscles will relax reciprocally and the buoyant suspension will adjust to the new and lesser degree of deformity. As each new and better position is gained the patient attempts to maintain it, first by holding and then by relaxing in that position. If it is necessary to adjust the length of ropes, the operator does so at this point with smooth action and no jerking.

Once the patient has accepted the sling support as a safe medium, then the relaxation can proceed more quickly and movements may be started. It is usually necessary to combine attempted movement with one of the above methods of gaining relaxation, as spasticity or increased unwanted movement may again be manifested as attempts are made to change the present position.

It is vitally important that joint range should always be maintained, and with a heavy and inert patient this is often a major problem. Since the weight is taken by the apparatus, and, as already pointed out, the relaxed state is more easily maintained, the physiotherapist may find that maintenance of joint range is facilitated by using these techniques.

In cases where unwanted movements are the cause of inco-ordination if the position is adapted to suit each individual, a period of relaxation in suspension will often result in a lessening of these movements. For example, in Parkinsonism during a period in suspension the unwanted movements diminish, and by virtue of the continued comfortable support the patient may then be able to practice controlled repetitive movements and so help to counteract the major disability, which is poverty of movement. In previously untreated adult cerebral palsy patients with marked athetosis relaxation in suspension is sometimes a useful preliminary to other forms of movement education.
so that the leg and arms may move in this hetero-lateral manner.

When flexor contractures, caused by persistent spasm are present, the support is modified so that it accommodates to the patient’s posture and position. Thus if the hips and knees are flexed the suspension would be applied as in Fig. 112.

The desirability or otherwise of using short tension or helical springs is again dependent on the response when they are tried. If the patient has true spasticity and not adaptive shortening of structures, then springs may be used in the suspensory units; the patient can then achieve a straightening of the limb as relaxation occurs, and spasticity is relieved without further alteration of the length of the supporting ropes. Experience with a particular patient is also the only means of deciding whether the buoyancy and increased length should be provided by short tension springs or by the longer helical springs. If the amount of spasticity is small and the position of deformity slight, then the short tension springs may be preferable. However, if the patient is apparently severely deformed by spasticity which will eventually be relieved during the treatment, then the long tension springs will probably be more suitable. In either case the poundage of the springs must be such that adequate support is offered in all positions.
so that combined oblique movements can be performed. The physiotherapist initiates the movement which is continued by momentum, so that repetitive movements are maintained for a short period. If this process is repeated, kinaesthetic sensation is stimulated; gradually the patient will be able to maintain the repetitive movements in the shoulder, and “overflow” into the elbow will often follow. Reciprocal pulleys can also be used with success in the restoration of self-activated arm movements. In the early stages it may be necessary to bandage the affected hand on to the handle until the grip is restored.

Owing to the complexity of symptoms and varying disabilities presented by patients suffering from inco-ordination, suspension therapy will be limited in its sphere of application, but, if applied with discrimination and initiative, it may provide a very useful phase in the treatment programme of these disorders.
In some cases where spasm and ataxia are both present and it is desirable to use sight as a substitute for "feeling", particularly if the legs are affected, combined treatment consisting of relaxation followed by movement can be carried out in suspension. The patient is placed in half-lying position so that he is able to see his legs, which are fully supported by vertical suspension. When some relaxation has been achieved, simple flexion and abduction movements can be practised, whilst the patient observes the movement. The arc of movement will be small, as vertical suspension will not permit a large range of movement, but the continued support of the slings will help to sustain a relaxed state and so make it possible for the patient to perform smoother and more controlled movements than if the fixation is disturbed.

Useful Modifications in the Treatment of Cerebral Catastrophe resulting in Hemiplegia

To restore combined movement of the arms and legs in preparation for walking in cases where there is little or no control of voluntary movement:

The patient is first placed in lying with all four limbs suspended and simultaneous movements of legs, then arms and then all four limbs encouraged. Progression is made by turning the patient first on to the affected side and then on to the sound side. In each position the uppermost arm and leg are suspended and swung backwards and forwards, first together and then the arm is swung forwards as the leg is swung back as in walking. Later, with the patient lying on the sound side, the affected leg and normal arm are suspended. The trunk is turned slightly backwards to free the arm to move, and as both limbs swing forward together the heterolateral action as in walking will be simulated. The process is repeated by turning the patient to the opposite side.

As the patient recovers the ability to perform these actions in the upright position suspension is no longer required.

To restore movement in the arm. Sometimes when treatment has been delayed control of all arm movements is lacking. In these cases the arm can be supported (as shown in Fig. 48),
Index
Abdominal exercises, 114, 125, 184

Acceleration, 54
Amplitude, 54
Amputation, 170-193
— of arm, 189-190
— bandaging, 187-191
— above elbow, 191
— below elbow, 191
— above knee, 187
— below knee, 190
— of leg above knee, 176-182, 183
— of leg below knee, 184-185
— oedema in, 187-188
— post-operative treatment, 173
— preparation for, 172
— pylons for, 190-193
— stump care, 184
— exercises, 176-178, 186-187
— lengths, 178
Anatomical considerations, 4
Angle of pull, 67-69
Ankle dorsiflexion, 119
— plantarflexion, 119, 190
Ankylosing spondylitis, 143-144
Arm abduction and adduction, 72
— exercises, 128
— flexion and extension, 70
— general movements of, 84
— rotation, 81-82, 181
— thrusting, 187
— treatment in poliomyelitis, 193
Arthroplasty of elbow, 193
— of hip, 191
Axilla, 208, 212
Axial fixation, 96
— variations from, 37-40

Contractures, flexion, 209
— in geriatrics, 209
Co-ordination, 23, 161
Crawling in suspension, 109-111

Deceleration, 34
Dislocation of elbow, 155
— of hip, 152
— of shoulder, 134-135
Distortion of springs, 86
"Dureros" socket, 190-192

Elasticity, 43
— loss of, 6
Elbow arthroplasty, 133
— dislocation, 135
— extension, 83, 122
— flexion, 83
— treatment in poliomyelitis, 149
Equilibrium, 33
Extensibility, 44

Fatigue, 3, 48
Femur, fractured neck, 132
— lower third, 132
Fixation, axial, 96
— variations from, 37-40
— vertical, 33
Flexor spasm, surgery for, 160
— treatment of, 160, 209
Foot, eversion, 139, 195
— inversion, 139, 150
Forces, application of, 67-69
Fractures and bed-chairs, 286
— of femur, 152-153
— of humerus, 134
— of radius, 135

Bell, Miss D. T., 147
INDEX  219

Paraplegia, compensatory training, 160-166
— co-ordination mechanisms, 161
— co-ordination exercises, 164
— electrotherapy in, 157
— flexion contractures, 156
— flexor spasms, 158-159, 160
— games for, 168-169
— general treatment of, 150
— and glossopharyngeal breathing, 168
— passive movements, 157
— physical restoration in, 155
— and positioning of limbs, 155
— and pressure sores, 152
— psychological aspects of, 153
— respiratory disturbance, 164-168
— skin care in, 151
— Stoke Mandeville bed-cycle for, 163
— suspension for, 162
— vasomotor control, 161

Penchant, 35-36

Periarthritis, 134-135, 142
Physiological consideration of suspension, 4
Polyneuritis, 136-140
Pogson, Sir Arthur, 11
Postural conditions, 148
Prime movers, 63
Psychological considerations, 4, 155, 172, 175
Pulleys, care of, 66
— circuits, multiple, 42
— reciprocal, 73-75
— compensating devices, 23-24
— description of, 23
— in hemiplegia, 413
— mechanics of, 41-43
— and weight, 73-77

Quadriceps, in knee conditions, 134
— re-education, 91
— treatment in poliomyelitis, 139

Radius, fractured, 135

Relaxation, 6
— in nervous disease, 209
— in suspension, 185, 186

Relaxed exercises for lower limb, 115-120
— for neck, 115-116
— for trunk, 113-115, 123-124
— for upper limb, 180-181, 122
Rheumatic conditions, 141-146
— anklyosing spondylitis, 143-144
— bed-chair for, 206-207
— non-articular, 141-142
— osteo-arthritis, 144-146
— rheumatoid arthritis, 142-143
Rhythm, natural, 34

Ropes, 19-81
— to adjust, 52
— care of, 50
— double, 19
— knots, 59
— single, 19

Sacro-iliac strain, 102-103, 144
Savage, Miss B., 141
Savin, Miss P., 194
Scapular movement, 82-83
Short tension springs, 66
Shoulder abduction, 79-81, 120
— extension, 82, 129
— flexion, 82
— frozen, 134-135, 142
— joint conditions of, 134
— oblique movement of, 82
Skin care, in amputations, 184
— in paraplegia, 151
Silages, 21-23
— body, 21
— care of, 50
— head, 21
— latex foam, 198
— single, 21
— standard positions of, 53
— three rings, 23, 54
Spasticity, 207-210
Spine in axial rotation, 96-97
— extension, 100-101, 113, 124
— flexion, 99-100
— lumbar region of, 95-96
— rotation, 114, 123
— side-flexion, 96-99, 115, 123
Spreader, for springs, 56
Springs, care of, 65
— helical, 26
## INDEX

<table>
<thead>
<tr>
<th>Fractures of vertebrae, 135</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frames, suspension, 16-18</td>
</tr>
<tr>
<td>Friction, 89</td>
</tr>
<tr>
<td>Frozen shoulder, 134-135, 141</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geriatrics, 194-207</th>
</tr>
</thead>
<tbody>
<tr>
<td>— approach to, 195</td>
</tr>
<tr>
<td>— care in, 196</td>
</tr>
<tr>
<td>— group work in, 201</td>
</tr>
<tr>
<td>— physiotherapy for, 196-202</td>
</tr>
<tr>
<td>— weight-bearing training in, 201</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gravity, 89, 34</th>
</tr>
</thead>
<tbody>
<tr>
<td>— centre of, 51</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Guthrie Smith, O. F., 9, 10, 11, 12, 13, 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guttman, L., 147, 148, 149</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hand exercises, 141</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head extension, 101-103, 116</td>
</tr>
<tr>
<td>— rotation, 101-102</td>
</tr>
<tr>
<td>Helical springs, 46</td>
</tr>
<tr>
<td>Hemplegia and bed-chair, 206</td>
</tr>
<tr>
<td>— treatment of, 219</td>
</tr>
<tr>
<td>Hip abductor, 86, 116</td>
</tr>
<tr>
<td>— adductor, 86, 118</td>
</tr>
<tr>
<td>— arthroplasty, 131</td>
</tr>
<tr>
<td>— dislocation, 134</td>
</tr>
<tr>
<td>— extensor, 86, 117</td>
</tr>
<tr>
<td>— flexor, 86</td>
</tr>
<tr>
<td>— oblique movements of, 89</td>
</tr>
<tr>
<td>— osteo-arthritis of, 132, 145</td>
</tr>
<tr>
<td>— treated in prone lying, 89</td>
</tr>
<tr>
<td>History of suspension, 9-14</td>
</tr>
<tr>
<td>Hooker's Law, 43</td>
</tr>
<tr>
<td>Horizontal resistance, 18</td>
</tr>
<tr>
<td>Huggan, Miss J. A., 128</td>
</tr>
<tr>
<td>Humerus, fractures of, 134</td>
</tr>
<tr>
<td>Hydrocortisone, 145</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inco-ordination, 208</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inertia, 33</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Knee, operations on, 133</th>
</tr>
</thead>
<tbody>
<tr>
<td>— resistance for, 119</td>
</tr>
<tr>
<td>Knots, 52</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Latex foam slings, 196, 199</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laws of motion, 33-35</td>
</tr>
<tr>
<td>Leg, abduction and adduction, 71</td>
</tr>
<tr>
<td>— extension and flexion, 71</td>
</tr>
<tr>
<td>— thrusting, 116</td>
</tr>
<tr>
<td>— treatment in polymyositis, 138</td>
</tr>
<tr>
<td>Leverage, balancing adverse, 43</td>
</tr>
<tr>
<td>Levers, 90</td>
</tr>
<tr>
<td>— and bed-chair, 203</td>
</tr>
<tr>
<td>Limb-fitting centre, 191-193</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical advantage, by leverage, 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>— with pulleys, 41</td>
</tr>
<tr>
<td>— considerations, 7</td>
</tr>
<tr>
<td>— of pulleys, 41-43</td>
</tr>
<tr>
<td>— of springs, 43-49</td>
</tr>
<tr>
<td>— of suspension, 46-49</td>
</tr>
<tr>
<td>— disadvantage, 34</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Moment of force, 39-32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Momentum, 6, 35</td>
</tr>
<tr>
<td>Motion, Laws of, 39-35</td>
</tr>
<tr>
<td>Movement, assisted, 72</td>
</tr>
<tr>
<td>Muscle control, 61</td>
</tr>
<tr>
<td>— power tests, 59-61</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Edema in amputation, 187</th>
</tr>
</thead>
<tbody>
<tr>
<td>— of arm, 107-109</td>
</tr>
<tr>
<td>— of leg, 107-109</td>
</tr>
<tr>
<td>Orthopedics, 127-140</td>
</tr>
<tr>
<td>Oscillation, 34</td>
</tr>
<tr>
<td>— of a pendulum, 35</td>
</tr>
<tr>
<td>— of springs, 44, 49</td>
</tr>
<tr>
<td>Oscillatory movement, of arm, 70</td>
</tr>
<tr>
<td>— of leg, 71</td>
</tr>
<tr>
<td>— test of muscle power, 60</td>
</tr>
<tr>
<td>— use of, 70</td>
</tr>
<tr>
<td>Osteo-arthritis, 132, 144-146</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Paraplegia, 147-159</th>
</tr>
</thead>
<tbody>
<tr>
<td>— balance in, 163</td>
</tr>
<tr>
<td>— bladder training in, 152, 153</td>
</tr>
<tr>
<td>— bowels, care of in, 153</td>
</tr>
<tr>
<td>— causes, 150</td>
</tr>
</tbody>
</table>
INDEX

Springs
mechanics of,
— oscillation in,
— in parallel,
— poundage,
— properties of,
— recoil of,
— in series,
— shock absorption in,
— short tension,
— wire diameter of,
Stability,
Stop in pulley circuits,
Strain and stress,
Supraspinatus strain,
Suspension, axial,
— for elevation of limb,
— fixation contracture modification,
— frames,
— for hemiplegia,
— and mechanical resistance,
— from mobile point,
— for movement of head,
— of lower limb,
— of trunk,
— of upper limb,
— for paraplegia,
— permanent,
Suspension for relaxation,
— technique,
— tests in,
— total,
— vertical,
— walking in,
Suspensory unit,
Talbot, Miss D. F.,
Tests,
— distance,
— halt,
— oscillatory,
— for relaxation,
Thompson, G. S.,
Triceps,
Velocity,
Walking in suspension,
— from a mobile point,
Weight arm,
— of body parts,
Yeoman, W.,