The Physiology of the Joints

I. A. KAPANDJI

Translated by
L. H. HONORÉ, B.Sc., M.B., Ch.B., F.R.C.P.(C)

Preface by
The late PROFESSOR G. CORDIER

Second Edition Reprint

Volume 2
LOWER LIMB

The Physiology of the Joints

Annotated diagrams of the mechanics of the human joints

I. A. KAPANDJI
Ancien Chef de Clinique Chirugicale
Assistant des Hôpitaux de Paris
Membre Associé de la Société Française D'Orthopédie et de Traumatologie

Translated by
L. H. HONORÉ, B.Sc., M.B., Ch.B., F.R.C.P.(C)

Preface by
The late PROFESSOR G. CORDIER
(formerly Dean of the Faculty of Medicine of Paris)

Second Edition Reprint

Volume 2
LOWER LIMB

1 The Hip
2 The Knee
3 The Ankle
4 The Foot
5 The Plantar Vault

With 618 illustrations by the Author

CHURCHILL LIVINGSTONE
EDINBURGH LONDON AND NEW YORK
1970

CHURCHILL LIVINGSTONE
Medical Division of Longman Group Limited

Distributed in the United States of America by
Churchill Livingstone Inc., 19 West 44th Street,
New York, N.Y. 10036
and by associated companies, branches
and representatives throughout the world.

First English edition 1970
Reprinted 1974
Reprinted 1975
Reprinted 1976
Reprinted 1977
Reprinted 1978
Reprinted 1980

ISBN 0 443 00655 5

The original French edition is entitled *Physiologie Articulaire* and is published by Librairie Maloine, Paris.

Printed in Hong Kong by
Yu Luen Offset Printing Factory Ltd.,

PREFACE TO THE FRENCH EDITION

This work belongs to a series of three volumes of which the first, on the upper limb, has had well-deserved success.

The same original approach has been adopted in this volume, devoted to the lower limb. The functional anatomy is clearly and precisely set forth with the help of six hundred and eighteen diagrams. The explanatory notes on the mechanics of the joints and the physiology of muscle action are at once brief and perfectly clear.

This new method makes the study of the anatomy and physiology of joints logical and simple. It will appeal to a wide public ranging from the medical student to the physiotherapist and the orthopaedic surgeon.

DOYEN GASTON CORDIER

CONTENTS

THE HIP 9

Movements of the Hip and their Ranges 10
Articular Surfaces and Structure of the Hip 24
The Capsule and Ligaments of the Hip 32
Coaptation of the Articular Surfaces 44
Flexor and Extensor Muscles 48
Abductor Muscles and the Transverse Stability of the Pelvis 52
Adductor Muscles 58
Rotator Muscles 62
Inversion of Muscular Action 66

THE KNEE 72

The Axes of the Knee 74
Movements of the Knee and their Ranges 76
The General Structure of the Lower Limb 80
Articular Surfaces 82
Movements of the Articular Surfaces during Flexion and Extension 88
Movements of the Articular Surfaces during Axial Rotation 90
The Capsule and the Infrapatellar Fold 92
The Menisci and their Function 96
Movements of the Patella on the Femur and Tibia 102
The Collateral Ligaments: their Function and the Transverse Stability of the Knee 106
Anteroposterior Stability of the Knee 112
Cruciate Ligaments and their Function 114
Rotational Stability of the Knee during Extension 124
Extensor Muscles of the Knee 126
Flexor Muscles of the Knee 130
Rotator Muscles of the Knee 132
Automatic Rotation of the Knee 134

THE ANKLE 136

Movements of the Ankle and their Ranges 136
Articular Surfaces of the Ankle 142
Ligaments of the Ankle 144
Anteroposterior and Transverse Stability of the Ankle 146
Tibiofibular Joints and their Function 150

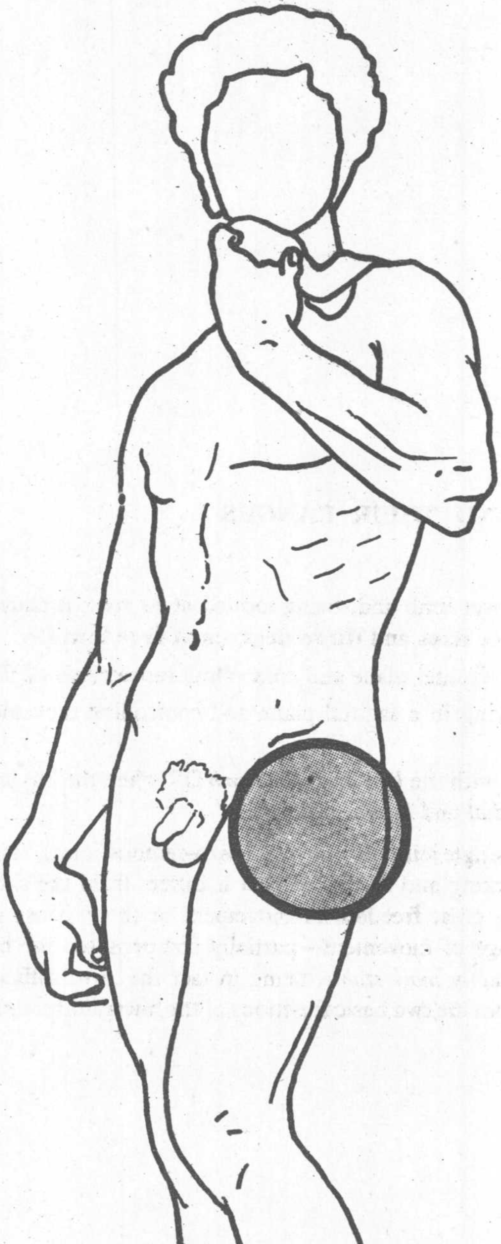
THE FOOT 154

Movements of Longitudinal Rotation; Side-to-side Movements 156
Subtalar (Talocalcanean) Joint 158
Transverse Tarsal (Midtarsal) Joint 162
Movements of the Subtalar and Transverse Tarsal Joints 166
Anterior Tarsal and Tarsometatarsal Joints 174
Extension of the Toes 176
Interosseous and Lumbrical Muscles 178
Sole of the Foot: Muscles and Fibrous Tunnels 180
Flexor Muscles of the Ankle 184
Extensor Muscles of the Ankle 186
Abductor-Pronator Muscles 192
Adductor-Supinator Muscles 194

THE PLANTAR VAULT (Arches of the Foot) 196

General Architecture of the Plantar Vault 198
The Three Arches of the Plantar Vault 200
Distribution of Stresses and Static Distortions of the Vault 206
Dynamic Changes of the Vault during Walking 208
Dynamic Changes Related to the Medial and Lateral Inclination of the Leg on the Foot 210
Adaptation of the Plantar Vault to the Ground 212
Claw Feet (Pes Cavus) 214
Flat Feet (Pes Planus) 216
Imbalance of the Anterior Arch 218

References will follow at the end of the last volume



THE HIP

THE HIP

MOVEMENTS OF THE HIP AND THEIR RANGES

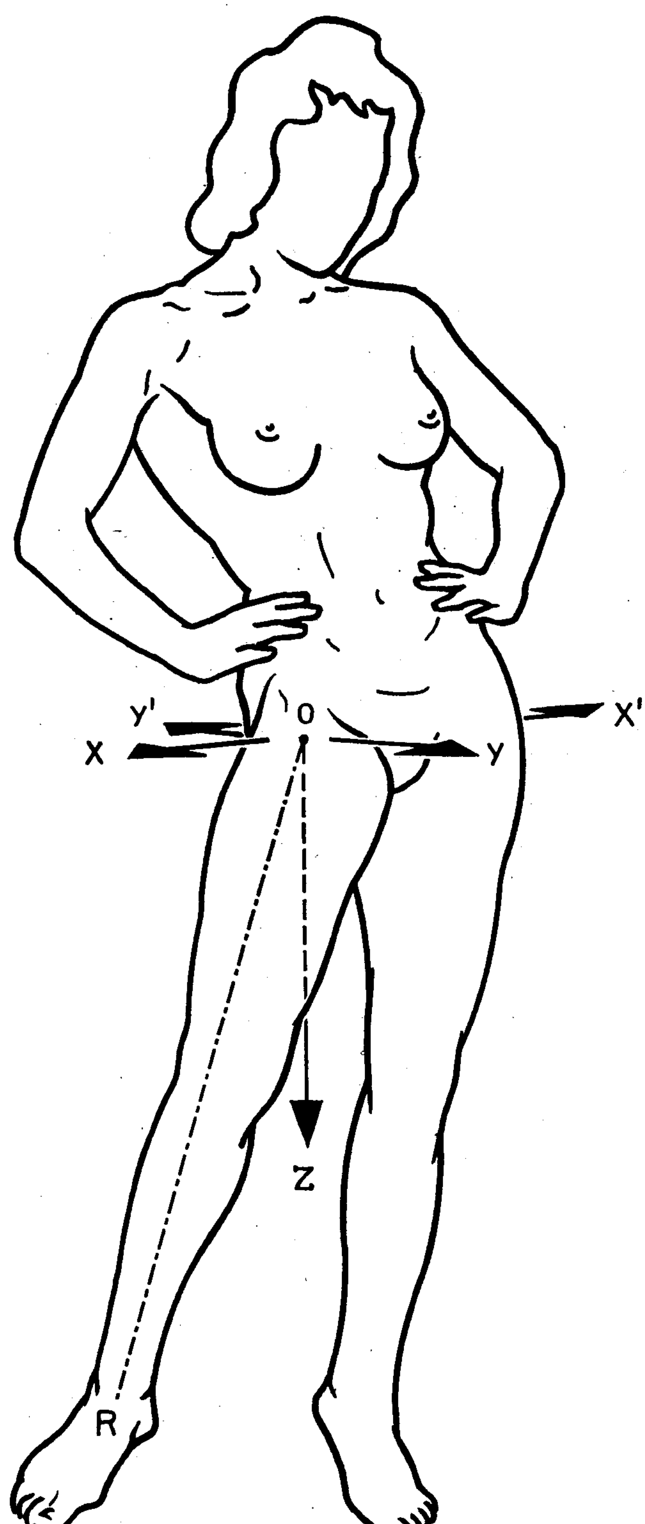
The hip is the *proximal joint* of the lower limb and, being located at its root, it allows the limb to *assume any position in space*. Hence it has **three axes** and **three degrees of freedom** (fig. 1).

A **transverse** axis XOX′, lying in a frontal plane and controlling movements of *flexion and extension*.

An **anteroposterior** axis YOY′, lying in a sagittal plane and controlling movements of *adduction and abduction*.

A **vertical** axis OZ, which coincides with the *long axis of the limb* OR when the hip joint is in the 'straight' position. It controls movements of *medial* and *lateral rotation*.

The movements of the hip occur at a single joint: the *hip joint* (coxo-femoral joint). It is a **ball-and-socket joint** with a marked degree of interlocking and in this respect it differs from the shoulder joint which is an open ball-and-socket joint showing great freedom of movement at the expense of stability. The hip joint therefore has a more limited range of movement—partially compensated for by movements of the lumbar vertebral column—but is distinctly *more stable*, being in fact the most difficult joint to dislocate. These features of the hip joint derive from the two basic functions of the lower limb: *support of the body weight* and *locomotion*.



1

MOVEMENTS OF FLEXION OF THE HIP

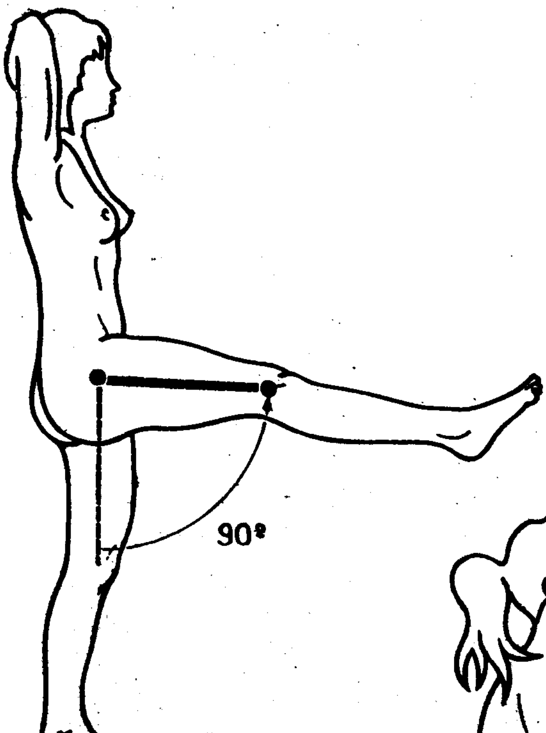
Flexion of the hip joint is *the movement which approximates the anterior aspect of the thigh to the trunk* so that the whole lower limb comes to lie anterior to the frontal plane, which traverses the joint.

The **range of flexion** varies according to the following conditions:

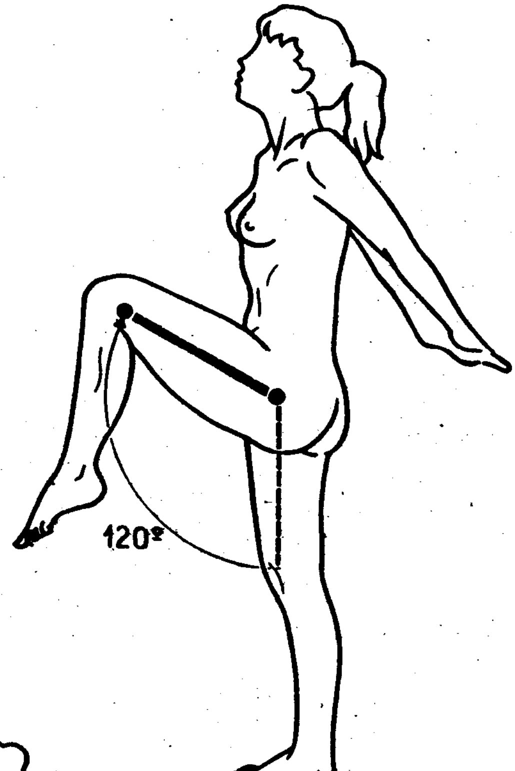
On the whole, *active* flexion is of lesser range than passive flexion. The *position of the knee joint* also determines the range of flexion: with the knee extended (fig. 2), flexion reaches 90°; with the knee flexed (fig. 3), flexion can reach up to 120° or even beyond.

The range of *passive* flexion always exceeds 120° but is still dependent on the position of the knee. If the knee is extended (fig. 4), the range of flexion is clearly smaller than if the knee is flexed (fig. 5), in the latter case the range exceeds 140° and the thigh is nearly in contact with the thorax. It will be shown later (p. 130) how knee flexion relaxes the hamstrings and allows a greater degree of flexion at the hip.

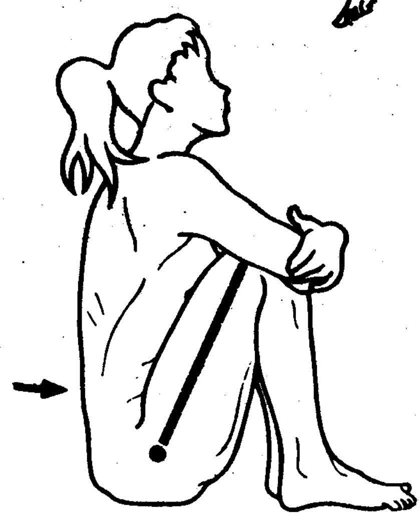
If both hips undergo passive flexion simultaneously while the knees are flexed (fig. 6), the anterior aspects of the thighs come into contact with the chest. This occurs because flexion of the hip is compounded with posterior tilting of the pelvis due to *flattening of the lumbar curve* (arrowed).



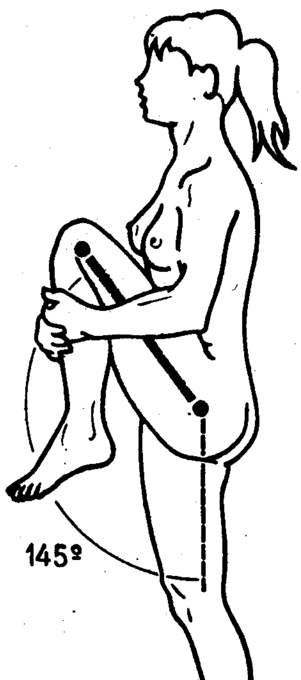
2



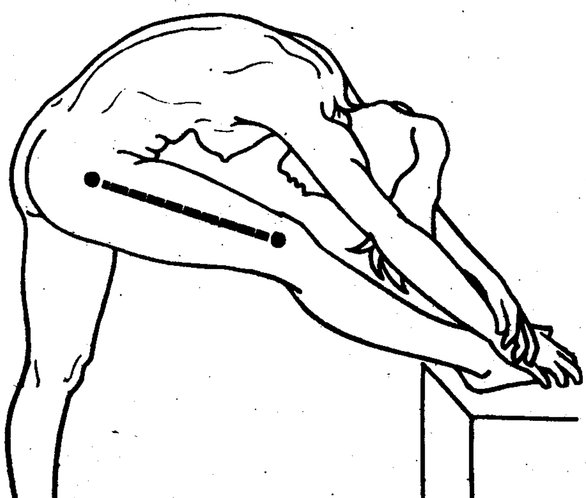
3



6



5



4

MOVEMENTS OF EXTENSION OF THE HIP

Extension takes the lower limb posterior to the frontal plane.

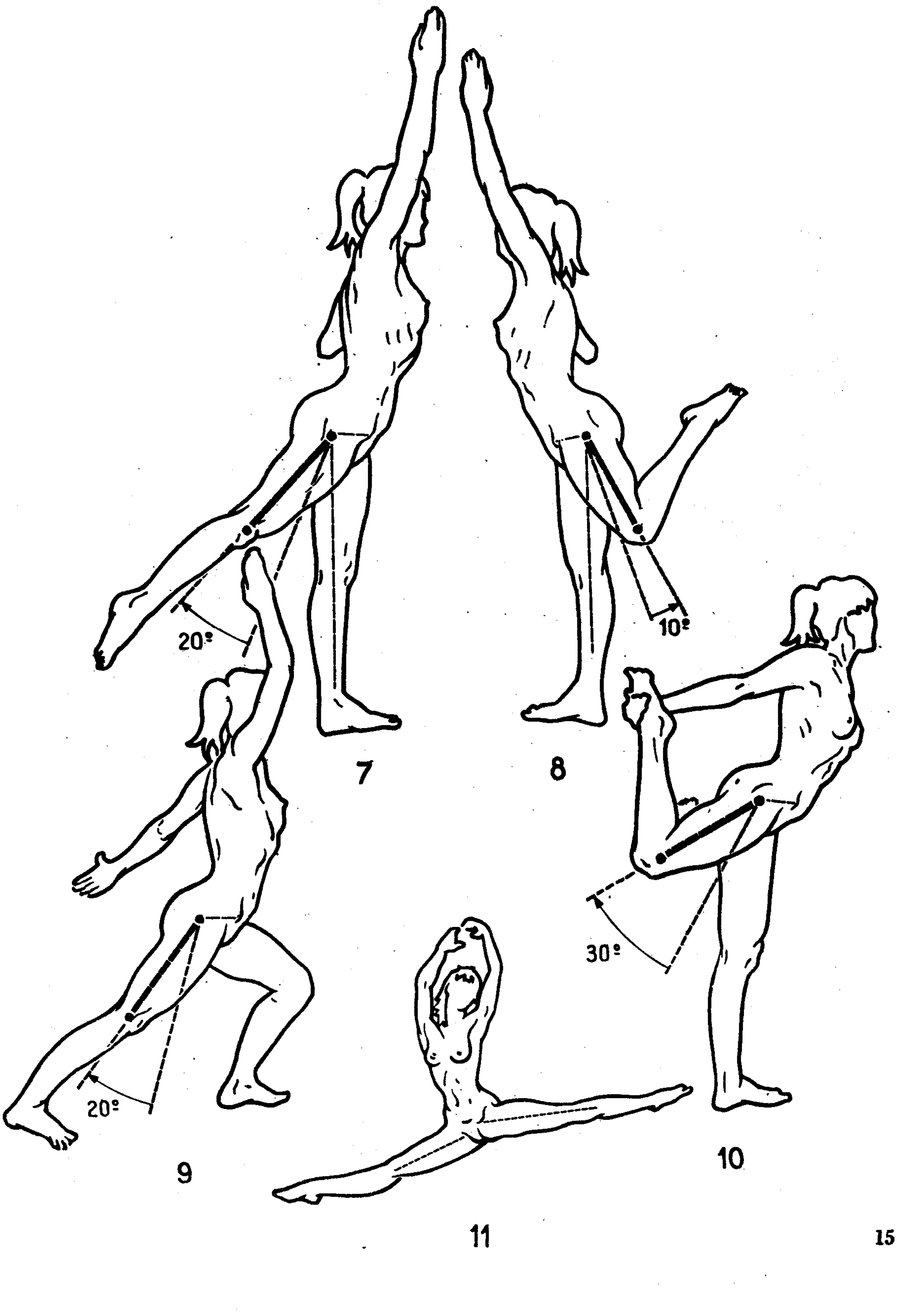
The range of extension is notably less than that of flexion and is limited by the tension of the *iliofemoral ligament* (p. 36).

Active extension is of lesser range than passive extension. When the knee is in extension (fig. 7), extension of the hip has a greater range (20°) than when the knee is flexed (fig. 8): this follows from the fact that the hamstrings lose some of their efficiency as extensors of the hip because their contraction has largely been utilised in flexing the knee (p. 130).

Passive extension attains a range of 20° when one bends forwards (fig. 9): it reaches 30° when the lower limb is forcibly pulled back (fig. 10).

Note that extension of the hip is appreciably increased by anterior tilting of the pelvis due to *exaggeration of the lumbar lordosis.* This contribution of the lumbar vertebral column to this movement of extension can be measured (figs. 7 and 8) as the angle between the vertical (fine broken line) and the 'straight' position of the hip (heavy broken line). This 'straight' position is easily determined because the angle between that position of the thigh and the line joining the centre of the hip and the anterosuperior iliac spine is a constant. However, this angle varies with the individual as it *depends upon the orientation of the pelvis,* i.e. the degree of anteroposterior tilting.

The values of the various ranges given apply to the 'normal' untrained subject. They are considerably increased by exercise and training. Ballerinas, for example, commonly do the splits in an anteroposterior direction (fig. 11), even, without resting on the ground; this is due to enhanced flexibility of the iliofemoral ligament. However, it is worth noting that they compensate for the inadequate extension of the posterior limb by an appreciable degree of anterior tilting of the pelvis.


20º
10º
7
8
20º
30º
9
10
11

MOVEMENTS OF ABDUCTION OF THE HIP

Abduction is the movement of the lower limb **directly laterally** and away from the plane of symmetry of the body.

It is theoretically possible to abduct only one hip but *in practice abduction at one joint is automatically followed by a similar degree of abduction at the other joint.* This becomes obvious after 30° abduction (fig. 12), when one first clearly notices tilting of the pelvis, as judged from the displacement of the line joining the surface markings of the two posterior iliac spines. If the long axes of the lower limbs are produced they intersect on the line of symmetry of the pelvis. This indicates that in this position each limb has been abducted 15°.

When **abduction reaches a maximum** (fig. 13), the angle between the two lower limbs is a right angle. Once more abduction can be seen to have occurred symmetrically at both joints so that each limb has a maximum of 45° abduction. The pelvis is now tilted at an angle of 45° to the horizontal and 'looks' towards the supporting limb. The vertebral column as a whole makes up for this pelvic tilt by bending laterally towards the supporting side. Here too the vertebral column is seen to *be involved in movements of the hip.*

Abduction is checked by the impact of the femoral neck on the acetabular rim (p. 32), but before this occurs it has usually been restrained by the adductor muscles and the ilio- and pubo-femoral ligaments (p. 40).

Training can notably augment the maximal range of abduction, e.g. ballerinas who can achieve 120° (fig. 14) to 130° (fig. 15) of *active* abduction without any support. For *passive* abduction trained subjects can attain 180° abduction *by doing the splits sideways* (fig. 16, a). In fact, this is no longer pure abduction since, to slacken the iliofemoral ligaments, the pelvis is tilted anteriorly (fig. 16, b) while the lumbar vertebral column is hyperextended i.e. the hip is now in a position of abduction and flexion.