The Clinical Management of Poliomyelitis

A Current View 2020

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Global HELP Organization

Preface

Many people have been misled to think that poliomyelitis is essentially extinct. While the worldwide incidence of polio has gone from an estimated 350,000 reported proven cases in 1988 to 74 cases in 2015 (1) the prevalence of Acute Flaccid Paralysis (AFP) in children was above 50,000 per year in India alone (2). In the past 40 years there have been persisting sporadic cases. It is critical to be aware that approximately only one child in 200 who gets the disease develops paralysis (3). The rest show few symptoms beyond malaise and diarrhea, which are common symptoms in childhood and easily overlooked. Thus, for every child reported to have polio, there may be as many as 199 other children with unrecognized active disease spreading the virus. Wild polio is widespread in sewage, and not just in underdeveloped regions. It was found in the sewers of Tel Aviv in 2013 (4). *It is our opinion that Polio is unlikely to ever be eliminated.* With continued vigorous vaccination worldwide, polio will only be controlled. There will be unpredictable sporadic outbreaks.

Those many thousands who currently live with paralysis due to polio and AFP still need care. Add to this, those with the polio-like AFM who also need treatments developed for polio. But as long as the thinking among health workers becomes fixed in the belief that polio has been eliminated, or is "just around the corner from being eliminated" the many lessons learned over the generations about how those with polio can be greatly helped by appropriate clinical techniques will slip into oblivion. The repository of this information is now in the hands of an ever-dwindling number of clinicians in their seventies and eighties who have treated such patients in their career.

We do not think that the material presented in this booklet is the be-all and end-all of managing poliomyelitis. It is a start. By bringing together information from a number of established experts, we hope it will be an evolving document and we welcome differences of opinion from others. Please direct them to us at hwatts@ucla.edu

Hugh G Watts, M.D.

Global Help Organization

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Helping people help themselves

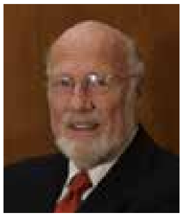
Global-HELP Organization (GHO) is very pleased to publish this booklet on the management of poliomyelitis. We consider this publication by seven authorities to be high quality, relevant, and current. The booklet is consistent with GHO's mission to create an open-access medical library of publications having lasting value that focuses on children's healthcare problems. We encourage management that is necessary, effective, safe, affordable and promotes the creation of sustainable improvements in healthcare throughout the world. GHO is a humanitarian organization that values diversity.

GHO's website has been accessed in 195 countries. GHO's annual activity includes downloads of about 250,000 pdfs and a total of about 400,000 YouTube videos views. Examples of some major publications include *Paediatric Surgery: A Comprehensive Text For Africa* (45,000 downloads) and *Clubfoot: Ponseti Management* (35,000 downloads).

We give special thanks to Deborah Cughan for creating the cover and converting the manuscript into a finished booklet. Deborah has been a longtime contributor to GHO. Most notably, Deborah designed the complex publication Paediatric Surgery for Africa which is used worldwide.

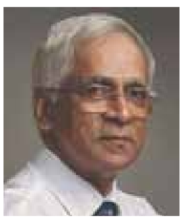
Lynn Staheli
Founder of GHO
Medical Director

Contributors



Dr. Watts, M.D.

Dr. Watts M.D. took his MD and orthopedic training at Harvard University. Subsequently he became the Chief of Orthopedic Surgery at the Children's Hospital in Philadelphia then moved to Saudi Arabia where he worked for five years at the King Faisal Specialist, Riyadh. In 1989 he joined the Shriners Hospital for Children in Los Angeles and retired as Clinical Professor of Orthopedic Surgery at UCLA. Dr. Watts has maintained a keen interest in health problems from a global perspective. He has lectured extensively world-wide, and has worked in Afghanistan, Cambodia, Columbia, Ecuador, Guatemala, Lebanon, Liberia, Lithuania, Mexico, Mozambique, Palestine, the Philippines, Sierra Leone, Tajikistan and Vietnam.

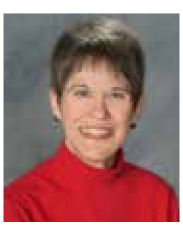


Dr. Benjamin Joseph

Dr. Benjamin Joseph took his medical degree at the Christian Medical College, Vellore, India, and his MS Orthopaedics at the Kasturba Medical College, Manipal, India. He then became the Professor of Orthopaedics and Head of the Paediatric Orthopaedic Service, the Department of Orthopaedics, Kasturba Hospital. He has lectured widely around the world, and is the author of seventy-six papers in peer-reviewed journals as well as chapters in five textbooks.

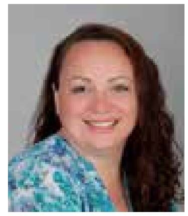
Dr. Fisk

Dr. Fisk is Professor Emeritus and a retired pediatric orthopaedic surgeon from Southern Illinois University School of Medicine. Before retirement as a part of his academic medical career he traveled and taught in many developing countries. He was the vice president of ISPO for two terms and is currently chairman of the board of Trustees of Exceed Worldwide, a UK charity that has organized schools for Prosthetics and Orthotics in five SE Asian countries.



Dr. Sharon DeMuth

Dr. Sharon DeMuth retired as an adjunct assistant professor of clinical physical therapy at the University of Southern California, Los Angeles, and specialized in physical therapy management of the pediatric patient. She received her BS in PT from the University of North Carolina, Chapel Hill and her MS in PT and DPT from the University of Southern California, Los Angeles. She has taught and practiced in Columbia, Ecuador, Lithuania, Mexico, Mozambique, Palestine, the Philippines, Tajikistan and Vietnam.

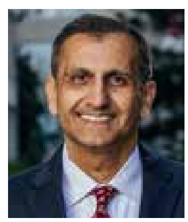


Helen Cochrane MSc. CPO(c)

Helen Cochrane MSc. CPO(c) is a Canadian Board Certified Prosthetist/Orthotist with a Masters Degree in Rehabilitation Sciences from the University of Strathclyde and both Technical and Clinical Diplomas from George Brown College in Toronto Canada. She has worked in prosthetic/orthotic education in South East Asia and in public and private clinical services. She currently works at Boundless Biomechanics Bracing in Mississauga ON.

Dr. Mathew Vorghese

Dr. Mathew Vorghese is a graduate and a post-graduate in orthopaedic surgery from Maulana Azad Medical College, University of Delhi. He is currently the Head of the Department of Orthopaedics, St Stephen's Hospital, New Delhi, and runs the last polio ward in the India. He welcomes visitors for training. His work caught the attention of Bill Gates, who considers him one of the five persons in the world who he thinks is a real-life hero.



Sanjeev Sabharwal, MD, MPH

Dr. Sanjeev Sabharwal is a Professor of Clinical Orthopaedics at the University of California, San Francisco (UCSF) and has a special interest in limb deformities and complex reconstruction. He is the Director and Chief of Orthopaedics at UCSF. He has a wide world view and worked with the children who were part of the large outbreak of polio in Tajikistan in 2010.

Deborah Cughan, Graphic Designer

Deborah Cughan is a native of the Pacific Northwest and received her B.A. in Visual Communications from Cornish College of the Arts in Seattle. She currently works as an Art Director in the travel industry where she gets to unite her two passions—design and seeing the world. Deborah has worked with Global-HELP since 2005 where she has contributed her graphic skills to help create publications such as the *Paediatric Surgery: A Comprehensive Text for Africa* as well as many translations of the *Clubfoot: Ponseti Management* book.

Contents

Introduction

Purpose of the manual

Though the number of new cases of poliomyelitis worldwide has dwindled considerably, the disease is by no means eradicated.There are also millions of people all over the world with untreated sequelae of poliomyelitis who would benefit from rehabilitative services, orthoses and surgery. In addition, the incidence of "poliomyelitis-like diseases" including acute flaccid paralysis (AFP) and acute flaccid myelitis (AFM) has increased. These children need essentially the same orthopedic care as those with confirmed poliomyelitis. In order to treat these patients effectively, it is important to understand the natural history of the original disease and also the altered biomechanics of a paralyzed limb or trunk. Comprehensive treatment of the effects of poliomyelitis entails inputs from a *team* that includes rehabilitation therapists, orthotists and surgeons. Not every statement is referenced. This manual is designed to be a useful summary of a clinical experience cumulated over many decades to help those faced with dealing with what is to many a new and strange disease.

Poliomyelitis

Poliomyelitis is an acute, non-progressive paralytic condition caused by a viral infection. It is primarily a disease of young children between the ages 1 to 4 years. Infants under six months of age are still protected by the mother's antibodies. In the late epidemics in the USA, young adults were also heavily stricken (most famously, Franklin Delano Roosevelt). This was due to the prolonged period of limited exposure to the disease and consequently poor immunity.

Pictorial depiction of people with withered limbs in Egyptian tombs dating back to 1500 BC suggests that poliomyelitis has been prevalent for thousands of years. It was not until early in the twentieth century that the causative virus was recognized. In 1930 three different strains of polioviruses were identified, and in 1949 the virus was cultured in the laboratory allowing the development of vaccines in the early 1950s.

Prevention of poliomyelitis and attempts to eradicate poliomyelitis

In 1954 a national trial of the Salk vaccination was conducted in the USA. This demonstrated that the injectable vaccine, using killed virus, was effective. Six years later Sabin developed the oral polio vaccine that uses live, but weakened, virus. The oral vaccine has been very effective in large-scale vaccination campaigns. In societies where the wild virus has not been reported for several years, the injectable killed virus vaccine is preferred in order to prevent vaccine related illnesses; however, the injectable vaccine is more expensive.

Under the World Health Organization global eradication initiative, a worldwide campaign was begun in 1988 to rid the world of poliomyelitis. That year there were 350,000 reported cases of poliomyelitis. In the year 2001 there were only 537 such cases. Unfortunately, some increases have been reported since, with 974 cases globally in 2010. The CDC reported six wild virus cases in 2016, five in Pakistan and one in Afghanistan. Strategies for poliomyelitis eradication include a strong routine immunization program, national immunization days, acute flaccid paralysis surveillance and "mopping up" immunizations.

To be declared "poliomyelitis free" a country has to have less than one case of acute flaccid paralysis (AFP– see below) per 100,000 children under the age of 15 years provided adequate screening programs are in place.

The western hemisphere was declared poliomyelitis-free in 1991, followed by Europe in 1998. The western pacific soon followed in 2000 and it was hoped that the virus could be eliminated in the sub-Saharan Africa and the Indian subcontinent shortly thereafter. However, recent cases in Syria and elsewhere show that the task is not complete. Currently, poliomyelitis is still epidemic in Pakistan and Afghanistan.

Problems confronting successful vaccination programs include difficulties with transportation, distribution, refrigeration and sterilization. Administrative, social and political factors, poverty and war can also hinder such programs. While many believe that poliomyelitis can be eradicated, a number of scientists think that this is not likely and recommend a policy of containment as being more realistic.

Pathogenesis of paralytic poliomyelitis

Poliomyelitis is an entero-virus infection; the organism enters through the G-I tract and spreads in the serum. It enters the central nervous system through peripheral nerve roots and migrates proximally to the anterior horn cells in the spinal cord where it causes nerve-cell injury and cell death. This results in paralysis of the muscle controlled by the damaged nerve cells.

Poliomyelitis spreads from one person to the next by the fecal-oral route through contamination of food and water. The virus is shed from the G-I tract for up to one month following infection. There is a seven to fourteen-day incubation period after exposure to the virus. Approximately 50% of those infected will show no clinical illness. Another 48% will only have an abortive illness consisting of muscle aches or headaches characteristic of an irritation of the meningeal linings of the brain and spinal cord. Less than 1% of those infected with the virus develop detectable muscle paralysis.

Patterns of paralysis

Cells of motor neurons of specific muscles are clustered in vertical columns within the anterior horns of the spinal cord. In the upper lumbar region, the cell columns innervating the proximal lower extremity muscles tend to be longer than those innervating the lower lumbar and sacral portions of the spinal cord. Consequently, a very small area of damage caused by the viral infection will have a greater impact on the muscles innervated by the lower lumbar and sacral regions.

The pattern of paralysis in poliomyelitis is characteristically asymmetric. Muscles that are affected most frequently are those that have all their anterior horns cells in a small, localized area in the spinal cord (e.g. tibialis anterior, quadriceps femoris, deltoid, opponens pollicis).

Recovery

The onset of paralysis is followed by a potential phase of recovery over the next six weeks when a variable degree of improvement in muscle strength occurs in two-thirds of affected individuals. The definition of muscle strength "recovery" is improvement by one manual muscle grade (see page 5; section on manual muscle testing). Several factors influence recovery including the age of the child, the severity of paralysis and the time since the onset of paralysis. Children recover faster than adolescents and adults. A muscle demonstrating no function after three months from illness will have no recovery. Early improvement in even a Grade 1 muscle has a good prognosis for a full recovery. Most of the recovery occurs in the first 12 months, there is only 5% recovery thereafter. There is no additional recovery of muscle function beyond 24 months after onset of the illness.

Recovery is facilitated by two mechanisms; first, there is resolution of intracellular edema in the anterior horn cells that have not died. These cells can then function quite well for several years but are vulnerable to degeneration later in life. Second, sprouting of axons from adjacent unaffected cells may supply motor end plates of cells that died. The resulting giant axons are also vulnerable to early degeneration.

Residual paralysis and its consequences

No additional recovery occurs after 24 months; therefore, the extent of paralysis at that point in time will remain permanently. The consequences of paralysis of muscles are motor weakness, muscle imbalance, joint instability and shortening of the limb. Muscle imbalance, in turn, can lead to contractures and deformities. Each of these needs to be evaluated by careful physical examination and treated appropriately.

Polio-like Diseases

a. Non-poliomyelitis acute flaccid paralysis (NP-AFP)

Some children develop muscle paralysis resembling poliomyelitis but the poliovirus cannot be cultured from their stool specimens and blood antibody level changes cannot confirm poliomyelitis infection. These children are labeled as having Non-Poliomyelitis Acute Flaccid Paralysis (NP-AFP). Their symptoms and sequelae may be identical to that of the child with poliomyelitis, and they will still need the same care as the child with confirmed poliomyelitis. It is possible that in some instances the failure to establish a diagnosis of poliomyelitis could have been on account of improper testing, but they too are regarded as cases of NP-AFP for epidemiologic purposes. Though India has been declared polio-free the numbers of AFP cases reported were 59436, 53421 and 53383 in 2012, 2013 and 2014 respectively.

b. Acute flaccid myelitis

Recently there have been reports of children who have developed poliomyelitis-like symptoms, including permanent paralysis where the poliomyelitis virus has not been grown out of stool specimens and there has been no rise in the poliomyelitis antibody titers. The Center for Disease Control reported 235 confirmed cases with this syndrome in 41 states in the USA for 2018 and a further 20 cases for 2019. It is presumed that the causative organism is an entero-virus similar to, but not actually poliomyelitis. No vaccines have been developed since a specific virus has not been identified. These children, too, need treatment similar to that needed in children with poliomyelitis.

c. Post-Poliomyelitis Syndrome

Many adults who had poliomyelitis in childhood experience increasing weakness in affected muscles much later in life. Symptoms may include fatigue, muscle pain, cold intolerance, atrophy of muscles and joint pain. These symptoms, which develop 30 to 40 years after the initial illness, are referred to as "Post-Poliomyelitis Syndrome". The new symptoms do not represent the reactivation of the virus but rather an aging of an impaired neuromuscular system with little reserve. It is very important that the term "post-polio syndrome" is reserved for this late manifestation and not used for the loss of muscle strength after the initial acute illness.

Diagnosis

A quick clinical guide to diagnosis

Poliomyelitis causes a *non-progressive, asymmetric, flaccid, motor paralysis or paraparesis.*

It is important to remember that if there is spasticity, it is not poliomyelitis and if there is sensory loss of any type, it is not poliomyelitis (Table 1).

Table 1: Diagnosis of poliomyelitis

What is poliomyelitis?	What is NOT poliomyelitis?	
A non-progressive asymmetric flaccid motor paralysis of acute onset heralded by high\ fever	Paralysis associated with spasticity	Sequelae of meningitis or cerebral malaria
		Complication of spinal tuberculosis
		Complication of Burkitt's lymphoma of the spine
		Lathyrism
		Tropical spastic paraparesis
		Konzo
	Paralysis associated with sensory loss	Guillain-Barré syndrome
		Post-injection paralysis
	Progressive paralysis	Tropical spastic paraparesis
	Paralysis not preceded by a febrile episode.	Complication of spinal TB or Burkitt's lymphoma of the spine, lathyrism, tropical spastic paraparesis, Konzo, post-injection paralysis

At the onset of paralysis, the conditions that may mimic polio include non-poliomyelitis acute flaccid paralysis and acute flaccid myelitis.

Confirmatory tests at onset of paralysis

Isolation of the virus:

The most sensitive method of confirming poliomyelitis infection in a child with acute flaccid paralysis is to isolate the virus from stool culture. To increase the chance of isolating the virus, two stool specimens 24 hours apart should be tested and the specimens should be collected within 14 days of onset of paralysis.

Real-time reverse transcription polymerase chain reaction(PCR) can differentiate wild strains of the virus from vaccine-like strains and partial genome sequencing maybe used to confirm the poliovirus genotype and determine its likely geographic origin.

Serologic testing:

Serology may support the diagnosis of paralytic poliomyelitis, particularly if the patient has not been vaccinated. A serum specimen should be obtained as early in the course of disease as possible, and a second convalescent specimen should be obtained at least three weeks later.

Diagnosis in a child or adult with residual paralysis following poliomyelitis

The diagnosis at this stage is entirely based on a history and clinical examination. A history of a febrile episode followed by flaccid paralysis in early childhood and asymmetric wasting, demonstrable muscle weakness, decreased muscle tone with intact sensations should confirm the diagnosis.

Examination of a Patient with Residual Paralysis

Muscle strength

Manual muscle testing

The strength of a muscle or a group of muscles serving a common function at a joint can be graded by manual muscle testing using a categorical scale ranging from 0 to 5 (see table). When done properly, manual testing of muscle strength is reproducible especially over the range of Grades 0 to 3.

Table 2: Grading of muscle power

Grade	Interpretation	Comment
Grade 0	No demonstrable muscle function No active motion of joint	No twitch of muscle
Grade 1	Twitch of muscle No active motion at joint	Twitch may be visible or palpable
Grade 2	Active movement of joint through full possible range of motion possible with gravity eliminated (i.e. movement in the horizontal plane)	If the child has a deformity or contracture at the joint the possible range of motion would be reduced The limb must be positioned appropriately
Grade 3	Active movement of joint through full possible range of motion against gravity (i.e. upward movement in the vertical plane)	The limb must be positioned appropriately If the joint moves against gravity for some of the range but not through the full range of motion a grade of 3 minus (3-) might be recorded, because the muscle is considerably better than a Grade 2
Grade 4	Active movement of joint through full range of motion against some manual resistance	May be difficult some times to distinguish from Grade 5
Grade 5	Full range of active motion against maximum resistance	Normal strength for the given age

Useful alternative clinical methods of testing muscle strength

Some muscles are hard to test by the usual hand pressure.

To evaluate the ankle plantar flexors (i.e. the gastrocnemius-soleus complex) we have to test them differently.

Ask the child to stand on one foot and then fully lift the heel off the ground (stand on tip toe) making sure that the child does not bend the knee during the heel lift. Ask the child to try to repeat the heel lift 25 times or as many times as possible if 25 lifts are not possible.

If 25 heel lifts are possible the ankle plantarflexor power is considered to be Grade 5; If 10 heel lifts are possible the ankle plantarflexor power is considered to be Grade 4;

If 5 heel lifts are possible the ankle plantarflexor power is considered to be Grade 3.

Dynamometry

Dynamometers, including hand-held ones, have been developed to quantify muscle power on a continuous scale.

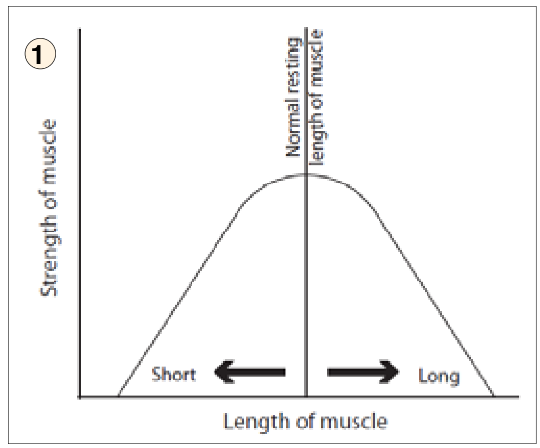


Figure 1: Graph showing how resting length of muscle affects the strength of the muscle

Muscle Physiology Important in Polio:

Length of muscle and its influence on muscle strength – Blix curve

The strength of a muscle depends on how much it is stretched or relaxed. A muscle is strongest when it is contracting from its normal resting length. When the muscle is stretched beyond that point, the muscle gets weaker. The same is true when the muscle is allowed to shorten to less than its normal resting length. This concept is illustrated in the Blix curve (see Figure 1).

This can be demonstrated when an object is grasped and squeezed as hard as possible with the wrist in the normal position of partial extension and again with the wrist maximally flexed and maximally extended. The grip strength is significantly less when the wrist is either maximally flexed or maximally extended.

This knowledge can be used to our advantage during manual muscle testing by positioning a joint so that surrounding muscles cannot be used to help a weakened muscle. For example, when testing the strength of the tibialis anterior muscle if the toes are flexed maximally the toe extensors cannot assist in dorsi-flexing the ankle and the strength of the tibialis anterior alone can be tested.

Long-term implications of muscle weakness in polio – Beasley's concepts

W. C. Beasley, in a very significant study, outlined the long-term implications of muscle weakness in a person with poliomyelitis.

He pointed out that grading of muscle power may be deceptive and may not reflect the true extent of muscle damage:

- Grade 5 power of the quadriceps femoris may be elicited with only 53% of normal quadriceps muscle strength
- Grade 3 power of the quadriceps femoris may be elicited with only 10% of normal quadriceps strength (i.e. it takes only 10% of normal quadriceps strength to fully extend the lower leg against gravity).

He also emphasized that the impairment may get aggravated with ageing:

- All people lose muscle strength with increasing age
- As a person with poliomyelitis becomes weaker with age he or she may drop to a grade 2 from grade 3 and not be able to function at his or her previous level.
- A person who might have been able to walk without bracing or crutches may need that additional level of support to continue walking when he or she gets older.
- The loss of function becomes even more challenging if we consider that the same will also be true for the muscles in the hand.
- It is easy for people with poliomyelitis to develop "over use" injuries.

Muscles frequently paralyzed in poliomyelitis

Since muscles responsible for virtually all movements of the extremities can be paralyzed to varying degrees in poliomyelitis it is important that the power of all these movements are tested at the concerned joints (see Table 3).

Other areas of muscle weakness in poliomyelitis

Muscles of the trunk can also be paralyzed and this may affect functions such as sitting and breathing. Asymmetric paralysis may also result in deformities of the trunk (scoliosis, kyphosis and lordosis).

Table 3: Muscles frequently paralyzed and joint movement that is weak

Joint	Active movement that is affected	Muscles paralyzed
Lower limb		
Hip	Flexion	Iliopsoas, rectus femoris
	Extension	Gluteus maximus, hamstrings
	Abduction	Gluteus medias, gluteus minimus
Knee	Extension	Quadriceps femoris
	Flexion	Hamstrings
Ankle	Dorsiflexion	Tibialis anterior, extensor digitorum
	Plantarflexion	Gastroc-soleus
Foot	Inversion	Tibialis posterior
	Eversion	Peroneus longus, Peroneus brevis
Upper limb		
Shoulder	Abduction (combined shoulder &scapulo-humeral motion)	Deltoid, supraspinatus, serratus anterior
	External rotation	Infraspinatus, teres minor
	Internal rotation	Subscapularis, pectoralis major, latissimus dorsi, teres major
Elbow	Flexion	Biceps brachii
	Extension	Triceps brachii
Hand	Thumb opposition	Opponens pollicus
	Finger flexion	Flexor digitorum profundus and superficialis

Common Lower Extremity Muscles Weakened by Polio

Hip

Flexion: Iliopsoas, Rectus Femoris
Extension: Gluteus Maximus, Hamstrings
Abduction: Gluteus Medias, Tensor Fascia Lata

Knee

Extension: Quadriceps
Flexion: Hamstrings

Ankle

Dorsiflexion: Anterior Tibialis, Extensor Digitorum
Plantarflexion: Gastroc-Soleus group

Foot

Inversion: Posterior Tibialis
Eversion: Peroneals

Common Upper Extremity Muscles Weakened by Polio

Shoulder

Scaption (*Scaption is a term used by Dr. Jaqueline Perry to describe combined shoulder flexion and abduction or combined gleno-humeral and scapular motion however, this term has not become generally accepted): (see Fig 5) Deltoid, Supraspinatus, Serratus Anterior; External Rotation: Infraspinatus, Teres Minor; Internal Rotation: Subscapularis, Pectoralis Major, Latissimus Dorsi, Teres Major.

Elbow

Flexion: Biceps
Extension: Triceps

Hand

Grip: Finger flexors and intrinsics

Other Muscles Affected by Polio

Trunk Muscles

Affects functions such as sitting and breathing or results in deformities of the trunk such as scoliosis

Facial Muscles

Affects functions like swallowing and breathing

Figure 2: Flexion, abduction and external rotation deformities of the hips, flexion deformities of the knees and plantar-flexion deformities of the ankles that developed in a child soon after an attack of poliomyelitis.

Figure 3: Severe flexion deformity of the knees following poliomyelitis that developed in a girl who has functioning hamstrings and paralyzed quadriceps femoris

Figure 4: Severe recurvatum of both knees in a boy with polio who has never used braces while walking. The capsules and ligaments have been excessively stretched.

Figure 5: This boy is unable to abduct his left arm at the shoulder. With the arm at neutral, the spine of the left scapula is almost horizontal (dotted line 8a). When he tries to abduct the left arm, the humerus barely moves but the spine of the scapula shows about 40 degrees of rotation (dotted line 8b). This indicates that the deltoid is paralyzed but the scapulo-thoracic muscles are functioning.

Joint deformities and range of motion of joints

Postural deformities

During the paralytic phase of poliomyelitis, the paralyzed limbs adopt a posture dictated by gravity; the lower limb is characteristically flexed, abducted and externally rotated at the hip, flexed at the knee and plantar-flexed at the ankle (Figure 2). Fixed deformities in this position may develop very soon with soft tissue contractures involving the fascia and joint capsules. These deformities are entirely preventable.

Deformities secondary to muscle imbalance

Deformities secondary to muscle imbalance develop over time (Figure 3) and again can be prevented or at least minimized by recognizing the muscle imbalance at joints and restoring muscle balance soon after the phase of recovery is over.

Deformities secondary to abnormal repetitive loading

Weight bearing on a deformed limb can accentuate a pre-existing deformity to a severe degree by stretching of ligaments and joint capsules and/or by adaptive bony deformity (Figure 4). Use of an appropriate brace that ensures normal alignment of the limb while walking can prevent progression of deformity.

Table 4: Common deformities of the lower limb encountered in poliomyelitis, their causes and consequences

Region / joint	Deformity	Cause	Consequence
Hip	Flexion	Contracture of Iliopsoas, Sartorius, Ilio-tibial band and tensor fascia lata, Rectus femoris, Anterior capsule of the hip joint	Compensatory lumbar lordosis
	Abduction	Contracture of Gluteus medius and minimus, Ilio-tibial band and Tensor fascia lata	Pelvic obliquity with obligatory adduction of opposite hip + Apparent lengthening of the abducted limb + Tendency for subluxation of the opposite hip
	Adduction	Contracture of adductors	Pelvic obliquity with obligatory abduction of the opposite hip + Apparent shortening of the adducted limb + Tendency for subluxation and dislocation of the deformed hip
	Flexion + Abduction + External rotation	Postural deformity with secondary contracture of soft tissues (fascia, joint capsule, muscles)	Walking bearing weight on the deformed limb may not be possible
Femur	Internal femoral torsion	Torsional deformity of the bone secondary to muscle paralysis	May facilitate walking with paralyzed quadriceps femoris with internal rotation of the hip
	External femoral torsion	Torsional deformity of the bone secondary to muscle paralysis	Out-toeing gait Knee instability due to quadriceps weakness will be more apparent
Knee	Flexion	Contracture of the hamstrings, ilio-tibial band, and the posterior capsule of the knee joint	If severe may preclude walking
	Recurvatum	Stretch of the posterior capsule and ligaments of the knee	Mild degree (~ 15 degrees) can help to stabilize the knee when the quadriceps is paralyzed
	Genu valgum	Iliotibial band contracture	Usually seen in association with flexion and abduction deformity of the hip
	Genu varum	Stretch of the lateral collateral ligament of the knee	Can progress over time and lead to instability of the knee

Tibia	Internal tibial torsion	Torsional deformity of the bone secondary to muscle paralysis	Can make a varus deformity of the foot worse
	External tibial torsion	Torsional deformity of the bone secondary to muscle paralysis	Can make a valgus deformity of the foot worse
Ankle and foot	Equinus	Postural deformity in the absence of muscle weakness or Weak ankle dorsiflexors + Contracture of the gastroc-soleus	Toe walking If unilateral, the limb appears longer and the child has to vault
	Equino-varus	Weak ankle dorsiflexors and evertors + Contracture of the gastroc-soleus and tibialis posterior	Walks on the outer border of the foot
	Equino-cavo-varus	Weak ankle dorsiflexors and evertors + Contracture of the gastroc-soleus, tibialis posterior and the plantar fascia	Walks on the outer border of the foot
	Equino-valgus	Weak ankle dorsiflexors and invertors + Contracture of the gastroc-soleus and the peronei	Walks on the inner border of the foot
	Calcaneus	Weak ankle plantar flexors, stretching of the Achilles tendon +/- Contracture of the tibialis anterior	Walks with a calcaneal "hitch" The deformity tends to progress over time
	Calcaneo-valgus	Weak ankle plantar flexors, weak invertors, stretching of the Achilles tendon +/- Contracture of the tibialis anterior	Walks with a calcaneal "hitch" The deformity tends to progress over time
	Pes planus	Isolated paralysis of the tibialis posterior	Often no functional disability
	First metatarsal drop (medial cavus)	Isolated paralysis of the tibialis anterior	If the deformity becomes rigid a compensatory varus deformity of the hindfoot can develop

Assessment of deformities of the lower limb

The common deformities at various joints of the lower extremities are shown in Table 4. While all deformities need to be identified, not all need to be quantified unless the severity has a bearing on management.

Deformities of all joints other than the hip can be clearly identified on inspection. Deformities of the hip, however, may be masked by compensatory deformities of the pelvis; these compensatory deformities need to be corrected by pelvic positioning during the exam, in order to identify the underlying hip deformity.

Assessment of deformities of the upper limb

Inability to actively abduct the shoulder is commonly seen due to paralysis of the deltoid. The scapulo-thoracic muscles are often spared (Figure 8). Arthrodesis of the scapulo-humeral joint in such a child may allow the arm to be voluntarily abducted motored by the intact scapular muscles. Other common deformities due to paralysis of the upper limb are shown in Table 5.

Joint instability

Instability at joints can occur as a result of three mechanisms (Table 6):

1. The muscles that are the dynamic stabilizers of the joint may be paralyzed.
2. Muscle imbalance may lead to joint subluxation
3. The ligaments and joint capsule that are the static stabilizers may be stretched and ineffective

Instability of a weight-bearing joint of the lower limb may compromise the ability to walk. Instability of a joint of the upper limb may impede some activities of daily living. The joints that are most prone to dislocate are the polyaxial joints like the hip and the shoulder. The radial head may also dislocate.

Table 5: Common deformities and paralyses of the upper limb encountered in poliomyelitis, their causes and consequences

Region / joint	Deformity	Cause	Consequence
Shoulder	Subluxation or dislocation	Loss of power of all dynamic stabilizers (muscles) + Stretch of the capsule with the weight of the limb	Inability to raise the arm and do any overhead activity Inability to use a walking aid if needed for ambulation
Elbow	Flexion	Contracture of the biceps brachii, brachialis and brachioradialis + Weakness of the triceps	If severe, use of a walking aid for ambulation may not be possible
Forearm	Supination	Contracture of the biceps brachii	Difficulty in positioning hand to pick up objects
Wrist	Flexion contracture	Contracture of wrist and/or finger flexors	Difficulty in grasping objects
Hand	Adducted thumb	Paralysis of the opponens pollicis	Inability to oppose the thumb and index finger Prehensile function impaired

Table 6: Pathologic mechanisms involved in causing joint instability in polio

Pathologic mechanism	Example	Nature of instability	Consequence of instability
Muscle weakness	Paralysis of gluteus medius and minimus	Instability of the hip in the stance phase of gait	Unstable, Trendelenburg gait
	Paralysis of quadriceps femoris	Instability of the knee in the stance phase of gait	Inability to walk unless the knee is stabilized by a hand on the thigh or with a brace (with the knee locked in extension in the stance phase)
Muscle imbalance	Weakness of hip abductors and extensors in the presence of functioning hip flexors and adductors	Hip subluxation or dislocation	Unstable, Trendelenburg gait
Muscle weakness + Ligament laxity	Flail shoulder + Stretching of capsule and ligaments	Inferior subluxation of the shoulder or Multi-directional instability	Over-all upper limb function severely compromised though hand function may be unaffected

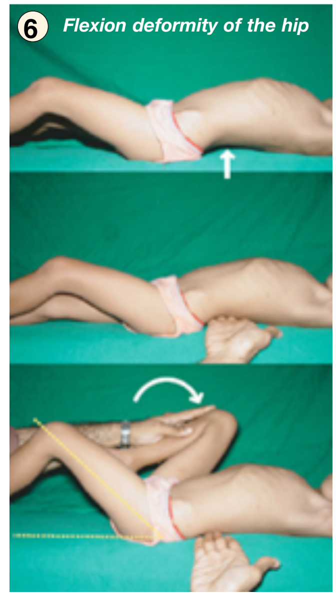


Figure 6: The Thomas test to demonstrate and measure flexion deformity of the hip. When the child is recumbent the exaggerated lumbar lordosis (straight arrow) masks the flexion deformity. The examiner places a hand under the lumbar spine and the unaffected hip is flexed till the lumbar lordosis is obliterated (curved arrow). The angle the thigh makes with the exam table is the degree of flexion deformity.

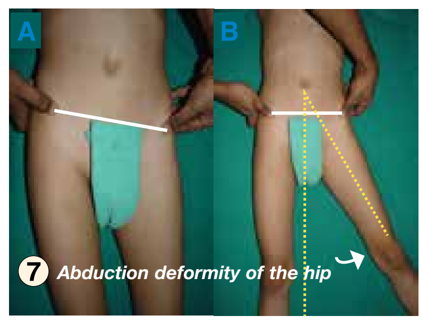


Figure 7: An abduction deformity is suspected when the pelvis is tilted such that the anterior superior iliac spine (ASIS) is at a lower level on the paralyzed side (a). This hip is abducted till the pelvis is "squared" (i.e. both ASIS are brought to the same level). The angle to which the limb is abducted is the degree of abduction deformity (b).

Figure 8: With the child lying supine with both thighs parallel and the legs hanging over the edge of the couch note if the lower leg is deviated away from the mid-vertical line the hip has an internal rotation deformity while if the leg is deviated towards the mid-vertical line (as shown above) the hip has an external rotation deformity. The angle the leg makes with the vertical is the degree of deformity. The child's right leg is deviated towards the mid-vertical line so the right hip has an external rotation deformity.

Limb length inequality

Limb length inequality is very frequently encountered among patients with poliomyelitis. The shortening usually affects the thigh, leg and foot segments and consequently each segment must be measured to identify which segment(s) are most affected.

Shortening of an upper limb very seldom causes functional limitations. Shortening of a lower limb, on the other hand, results in altered walking mechanics. Uneven leg lengths can also increase the energy consumption, which in turn, limits the distance the patient can walk. The patient may compensate for shortening of one limb by tip-toeing on the shorter limb or by flexing the knee of the longer limb. If the patient does not use either of these compensatory measures, the pelvis will remain tilted with uncovering of the femoral head of the higher hip (Figure 9).

Scoliosis may result in an apparent limb length discrepancy, or exacerbate a true shortening (Figure 10).

Figure 9: An adult with limb shortening on the left due to polio showing the pelvic obliquity.

Figure10: Scoliosis of the lumbar spine to the left has resulted in an apparent shortening of the right lower limb

Techniques of measuring leg length differences:

1)Blocks:

The simplest and most effective method, by far, is examining a patient's iliac crests using variable height blocks under the short leg to level the pelvis (Figure 11). In many patients, especially those that are more obese, it can also be useful to have the patient bend forward and examine them from behind to evaluate the levels of the posterior iliac crests.

2) Use of the measuring tape:

The "true leg length discrepancy" is measured from the anterior superior iliac spine to the medial malleolus (Figure12). This is a reasonably accurate measurement, but does not take in to account shortening that may be due to deformities of the foot or pelvis.

The "apparent leg length" is measured from the umbilicus to the medial malleolus. If the patient has a lumbar scoliosis, or if one leg is abducted and the other leg is adducted due to contractures the abducted leg will appear to be longer than the adducted leg.

3) Measurement by x-ray:

This requires the use of a radio-opaque ruler placed on the film while the x-ray is being taken. The x-ray itself can be taken in one of several ways, depending on the size of the patient and the film available.

4) CT scan:

A Computerized Tomography Scan (CT scan) can be used. It does not provide any extra benefit and is more expensive. Furthermore, it is usually not available in most the clinics that deal with poliomyelitis.

Function

After assessing individual impairments including muscle weakness, joint deformity and reduced range of motion, joint instability and limb length inequality it is important that the functional limitations arising from these impairments are assessed. Because the function of children or adults with poliomyelitis is dependent on the action at multiple joints, it is worth emphasizing the importance of examining the "whole" patient and not just the area or joint of specific complaint or interest. It is critical to understand what activities the patient does, or what functions the patient performs.

One helpful system for describing function is the International Classification of Functioning, Disability and Health (ICF). The ICF is the World Health Organization's (WHO) framework for measuring health and disability at both individual and population levels. The ICF helps to identify functional limitations or activity limitations that may be defined as "difficulties an individual may have in the performance of specific activities".

Categories of function or activity evaluated in the ICF include:
1. Learning and Applying Knowledge
2. General Tasks and Demands
3. Communication
4. Mobility
5. Self care
6. Domestic Life
7. Interpersonal Interactions and Relationships
8. Major Life Areas
9. Community, Social and Civic Life

Categories 4thru9would be impacted in a patient with the residua of poliomyelitis; categories 1 to3may be affected but less so (Table 7).

Table 7:

Activity	Examples of activity limitation in polio
Learning and Applying Knowledge	Learning to write
General Tasks and Demands	
Communication	Using communication devices and techniques (e.g. computer)
Mobility	Transferring oneself; Walking; Moving around using equipment
Self Care	Combing hair, bathing, dressing including doffing and donning footwear or orthosis
Domestic Life	Preparing meals; Doing housework
Interpersonal Interactions and Relationships	Intimate relationships
Major Life Areas	School education; Work and employment; Economic self-sufficiency
Community, Social and Civic Life	Recreation and leisure

Determining how the disease has affected the person's life by classifying the activity limitations or level of participation helps us understand what they can or cannot do and plan our intervention or treatment accordingly.

Upper limb function

Pre-operative evaluation needs to include more than the range of motion and muscle strength in the isolated joint in the upper extremity. The important question to ask is "What function does the patient need to do that the patient cannot do at the present time? What needs to be done to allow the hands to be freed up to use for manipulation? For example: "Does the elbow have sufficient motion and flexor power to get the hand to the mouth for feeding?"

It needs to be emphasized that function of the hand and wrist is the most important component of upper limb function. Normal shoulder, elbow and forearm function facilitates placement of the hand in a position to perform its function. While a totally functionless hand will render the upper limb limited function, observing people who have had poliomyelitis show this statement requires modification. The ability to adduct the upper arm against the chest wall provides many with active power to grasp objects.

Though the upper limb is a mechanism to place the hand in space where it is needed to perform necessary functions one should not ignore the person's use of the upper extremities to support the body weight with crutches, or to shift trunk weight by leaning on the arm rest of a wheelchair, or even the ability of a patient to grasp objects between the humerus and the chest wall. Shoulder stability is an important factor in order to use the elbow flexor muscles that cross both joints (i.e. the biceps). Following a shoulder fusion, many people find they have much better use of their hands and elbows; for this reason, we prefer to consider the shoulder first.

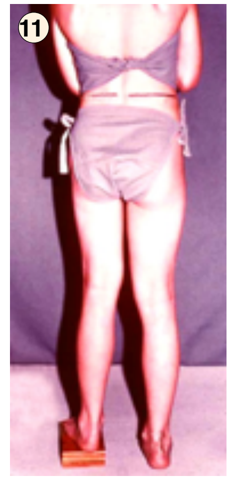


Figure 11: Blocks of known thickness placed under the shorter limb to level pelvis to estimate limb-length inequality. This estimate includes any shortening in the foot, tibia, femur and pelvis.

Figure 12: "True leg length" is measured from the underside if the anterior superior iliac to the tip of the medial malleolus.

Hand function

The basic functions of the hand are grasp and release; these functions can be evaluated easily by asking the person to grasp an object and then to hand it to the examiner. The fine functions of the hand or the prehensile functions entail opposition of the thumb to the index and middle finger as in holding a pencil, a paintbrush or a needle and thread.

Once it is clear that some useful hand function is present it is important to test if self-care activities of daily living are possible (Table 8).

Table 8: Tests for upper limb function with reference to self- care activities of daily living

Region being tested	Activity	Functional ability
Hand function	Grasp and release object	Basic hand function present
	Writing with a pencil	Prehensile function of hand present
Forearm and elbow function	Getting hand to mouth	Hand can be positioned to perform function
Forearm, elbow and shoulder function	Getting hand to perineum	
	Getting hand to the top and back of the head	
Hand, wrist, forearm and shoulder function	Combing hair with comb or brush	Hand can perform useful self-care activity
	Brushing teeth with a tooth brush	
	Plaiting hair	
	Buttoning the top button of a shirt	

Weight-bearing function of the upper limb:

If walking aids like crutches are needed for ambulation, the upper limbs have to take on a weight-bearing function. In order to use crutches effectively, grasp should be strong, the elbow and shoulder must be stable and the triceps brachii and latissimus dorsi should be of near normal strength.

A quick method of testing the potential weight-bearing function of the upper limbs is to ask the child to sit up and press down onto the chair or cot with both palms resting close to the body and raise the buttocks off the chair or cot. If this position can be held for 15 seconds it should be possible for the person to use crutches effectively.

Lower limb function

The function of the lower limbs is to enable standing and walking. Test if the child can stand without support. Independent unsupported standing may not be possible on account of muscle weakness, joint deformities, joint instability or a combination of these factors.

If the child can stand and walk the pattern of gait needs to be evaluated.

Muscle weakness, joint instability, deformity and limb length inequality can all contribute to altered gait (for a summary of the normal gait cycle and the attributes of normal gait see Appendix I).

Observing a patient's gait:

Perform a systematic assessment of the gait pattern as outlined in Table 9. Observe and record what is happening at the foot, knee, hip and trunk through the stance and swing phases of the gait cycle while viewing the patient from the front, back and sides. It may be necessary to observe each limb through several cycles to detect all the gait alterations.

If the patient is using a walking aid or orthotic appliance repeat the examination of the patient with and without the patient using the aids. This can help to decide if the walking aid that the patient is using is truly helping or actually hindering the patient.

Early Management of a Child the Episode of Acute Flaccid Paralysis

While the focus of this manual is on the child with Poliomyelitis, children who have suffered an episode of unspecified Acute Flaccid Paralysis (even though not proven to be poliomyelitis) or Acute Flaccid Myelitis are all managed in exactly the same way.

Early care

The most important goal after an episode of acute flaccid paralysis of any etiology is to prevent contractures. A variety of muscles may be affected, and it may be many months before it is known which muscles will recover totally, and which will remain partly or totally paralyzed. During that time the child should not sit or lay in positions that predispose to development of deformities so that when muscles do recover, they will not have to fight against such contractures.

Passive range of motion exercises, appropriate positioning and limited splinting are the main strategies for preventing deformities. Hip abduction and ankle equinus contractures can be effectively prevented by these simple measures.

Table 9: Assessment of gait

Side: Left lower limb / Right lower limb (to be recorded separately)			
Plane	**Phase of gait cycle**	**Joint or body segment**	**Abnormality to look for**
Coronal plane: Assessed as patient walks towards examiner and then away from the examiner (patient viewed from the front or back)	Stance phase	Foot & ankle	In-toeing / Out-toeing Hindfoot: Valgus / neutral / varus Forefoot: Supinated / neutral / pronated
		Knee	Genu varum / neutral / valgum
		Hip	Trendelenburg gait +/- Internal / neutral / external rotation
		Pelvis	Pelvic obliquity +/-
		Trunk	Sway +/-
	Swing phase	Foot & ankle	Hindfoot: Valgus / neutral/ varus
		Knee	Patella: Facing internally / neutral / externally
		Hip	Internal / neutral / external rotation
		Pelvis	Pelvic obliquity +/-
		Trunk	Sway +/-
Sagittal plane: Assessed as patient walks from left to right and from right to left of the examiner (patient viewed from side)	Stance phase	Foot &ankle	Foot contact sequence in stance: Heel-toe / toe-heel / toe-toe sequence Calcaneal hitch +/-
		Knee	Flexion / neutral / recurvatum
		Hip	
		Pelvis	Tilted forwards +/-
		Trunk	Lordosis: Exaggerated / not exaggerated Leans forward / leans backward
	Swing phase	Foot & ankle	Plantar-flexed / dorsiflexed
		Knee	Flexed
		Hip	Excessive flexion +/-
		Pelvis	
		Trunk	

Rehabilitation in the stage of recovery

For the first year or two after the acute episode of paralytic poliomyelitis some of the muscles will recover some or all of their initial strength. While waiting for this recovery, most children can be made to function better by preventing deformities and by improving the function of available muscles by specific exercises, surgery and bracing.

If the patient is older than 1 year of age, it is important to get the child walking as soon as possible in any fashion and not get bogged down by a vision of walking perfectly. While the child may ultimately be able to walk without orthoses after appropriate releases, tendon transfers and osteotomies, one does not need to do all such surgery at this stage. The aim should be to get the child up on his or her feet.

Surgery

If any contractures have developed and if they are an impediment to orthotic fitting they must be corrected with the simplest of soft tissue releases. The contracture releases that may be required at this stage are most often release of the hip flexors and abductors (Soutter release), the fascia lata distally (Yount release) and lengthening of the heel cord (Achilles tendon). The extent and duration of the deformities will dictate the techniques chosen.

Orthoses

Orthoses should be kept simple. If the treating physician is undecided whether to brace below the knee or above the knee, it is better to err on the side of more extensive bracing initially. While a "Floor Reaction Ankle-Foot Orthosis" (also known as a Pre-Tibial AFO; or Anterior Wrap orthosis) in slight ankle equinus might ultimately work to stabilize a patient with weak quadriceps, a person who has never walked before may well become frustrated without the instant stability provided by a simple long leg orthosis (i.e. KAFO). Such a person may have a great deal of difficulty learning to stand, let alone walk. This lack of initial demonstrable success from your efforts may result in the patient disappearing back to where he had been crawling about, with his family convinced of the uselessness of modern medicine.

For the same reason, the use of a walker may be the wisest initial choice of a walking aid. Later, progress can be made to axillary and then forearm crutches.

Management of Permanent Paralysis

It is all too easy to focus on a single deformity or a single limb; one needs to establish an overall program of treatment. In order to do so, priorities need to be established. Thorough assessment is the cornerstone of priority setting regardless of the age of the patient. Assessment of the person's gait (if he or she is a walker) with and without crutches and braces, sitting capabilities, passive and active range of motion and manual muscle testing of the extremities and trunk are basic. Limb length discrepancy and scoliosis should not be overlooked.

The most difficult assessment that is of vital importance is social and cultural assessment. Patient information is often gathered through the filtering process of an interpreter and analyzed with limited understanding of local needs, uses and geography. As often as not, it is these social and cultural factors, which become paramount in the success or failure of treatment.

Setting Priorities

The priorities of management are, by and large, sequential:

1. Get the patient to walk
2. Prevent and correct deformities
3. Obviate a lifetime dependency on an orthosis or reduce the extent of bracing
4. Correct upper extremity problems
5. Treat scoliosis

Getting the patient to walk

Many patients who first present have never walked. For a health care worker there can be few things as satisfying as converting a teenager, who has spent all of his/her life crawling, into an upright walker after relatively simple surgery, bracing and therapy. However, before embarking on multiple surgeries, the most important question to be asked is **"Can this person ever be converted into a walker?"** As obvious as this may seem, we have been consulted on many patients who had undergone multiple procedures to no avail because the basic ingredients for walking were not present.

An outline of the factors that influence the likelihood of walking is shown in Table 10.

Poor motivation of the patient and obesity can become critical impediments to walking in the marginal cases.

Orthotic management

Unless the antigravity muscles of the lower limb are spared or the extent of paralysis of these muscles is mild, some form of bracing will be needed to facilitate walking.

It is important that the general principles of bracing are kept in mind while prescribing the orthosis.

- Leave as many joints as possible free (i.e. unlocked) as energy consumption increases considerably when joints are locked.
- Ensure that the orthosis is as light as possible to minimize energy expenditure and consequently light-weight thermoplastic orthoses are preferred to traditional metal and leather orthoses.
- Areas of contact of the orthosis and the limb should be as large as possible with good surface matching of the orthosis to the body segment as poliomyelitis results in pronounced muscle atrophy and reduced soft tissues over bony prominences that have low pressure tolerance.
- Lever arms should be designed to be as long as possible so that the pressure is minimized, and the straps used to maintain contact between the orthosis and body segment, should be as large as practical (Figure 13).
- Wherever possible, attempt to discard the orthosis by the time the child is skeletally mature by surgical methods of stabilization.

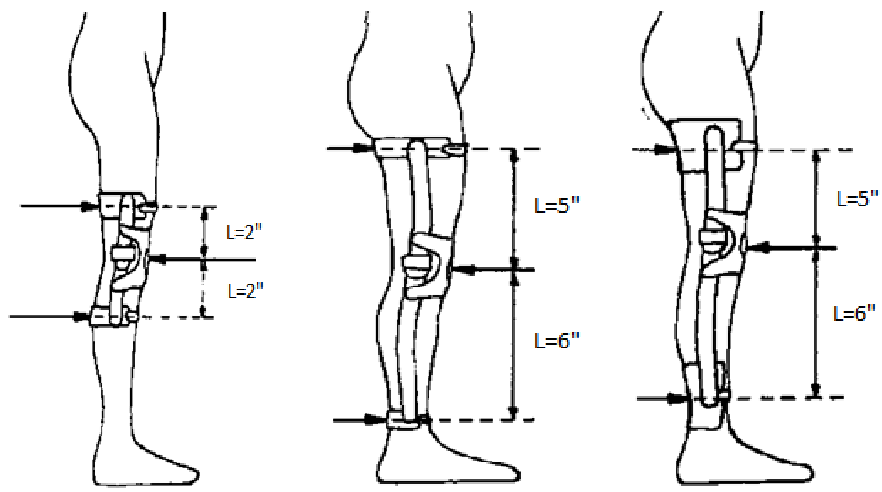
Table 10: Factors that influence the ability to walk

Lower limbs		Status of upper limbs	Status of the spine	Likelihood of walking
Status of more severely affected lower limb	**Status of opposite lower limb**			
Any severity of involvement	Normal	Normal or affected	Normal or affected	Excellent (with or without orthosis or crutches)
Any severity of involvement	Mild impairment	Normal or affected	Normal or affected	Excellent (with or without orthosis or crutches)
Severe involvement	Severe involvement	Normal or mildly affected	Normal or mildly affected	Good with orthosis and crutches
Severe involvement	Severe involvement	Inadequate strength*	Normal or affected	Unlikely to walk

**: A useful guide of a person's ability to use his upper extremities to assist weak lower limbs is to ask the patient to sit up and place his or her hands on the examining table and to push down and lift the buttocks off the surface. Inability to do so is a bad omen.*

13

Reduction of pressure by using longer lever arms and increased areas of contact, when applying corrective forces to the knee joint.



A: Short lever arms
Small contact Area
Resulting high pressures

B: Long lever arms
Small contact area
Resulting lower pressures

C: Long lever arms
Large contact area.
Resulting lowest pressures

Figure 13

Table 11: Factors that determine the type of knee joint to incorporate in a traditional orthosis

Age of the child	Side requiring bracing	Quadriceps power	Type of knee joint to be used in orthosis
Under the age of 5 years	Unilateral or bilateral brace	Grade III power or less	NO knee joint
Over 5 years of age	Unilateral or bilateral	Grade III power	Posterior offset knee joint
Over 5 years of age	Unilateral	Less than Grade III power	Drop lock knee joint
Over 5 years of age	Bilateral	Less than Grade III power	Swiss knee joints (syn. bail lock)

The orthotic knee joint

Once the child begins to walk the need for including knee and ankle joints must be considered. Since the child must be old enough to learn to lock the knee joint while standing and unlock it while sitting, including a knee joint in the orthosis may be deferred till the child is five years of age. The type of knee joint that is to be incorporated in the orthosis will vary with the age, the need for bilateral bracing and the quadriceps power.

The extent of bracing

The extent of bracing needed in the phase of residual paralysis depends on the muscle power around the hips, knees and ankles; if the quadriceps power is better than grade 3, bracing need not extend proximal to the knee. An outline of indication for bracing of the lower limb in poliomyelitis is shown below.

Mobility aids

Even after correcting deformities and appropriate bracing is provided the person may not be able to walk without the help of a walking aid. The need for a walking aid is dependent on the extent and severity of paralysis. In general, a walking aid is not required if the quadriceps power is grade IV or V on both sides even if bilateral ankle-foot-orthoses are required. If bracing above the knee is required on one lower limb, some patents may manage without a walking aid though some will need a walking aid. If bracing above the knee is required bilaterally a walking aid will be needed.

The options include a walker, axillary crutches or Lofstrand (elbow) crutches and the patient should use whatever he or she is most comfortable with.

Table 12: Indications for bracing of the lower limb in children in the phase of residual paralysis following poliomyelitis

Indications	Aim	Orthosis
Quadriceps power Grade IV or V Foot drop No fixed deformity Tendon available for tendon transfer but child too young to co-operate with rehabilitation after transfer	Prevent foot drop during swing phase Overcome high-stepping gait Prevent rigid equinus from developing before the tendon transfer is done	Thermoplastic ankle foot orthosis with trim lines posterior to malleoli – leaf spring orthosis (to be worn till tendon transfer is done)
Quadriceps power Grade IV or V Dynamic equinovarus or equinovalgus (no fixed deformity) Tendon available for tendon transfer but child too young to co-operate with rehabilitation after transfer	Prevent rigid equinovarus or equinovalgus from developing before the tendon transfer is done	Thermoplastic ankle foot orthosis with trim lines anterior to malleoli (to be worn till tendon transfer is done and 6 months following tendon transfer)
Quadriceps power Grade IV or V Dynamic equinovarus or equinovalgus corrected by tendon transfer	To protect the transferred tendon from stretching and becoming ineffective	Thermoplastic ankle foot orthosis with trim lines anterior to malleoli (to be worn for 6 months following tendon transfer and then discarded)
Quadriceps power Grade III or less No flexion or recurvatum deformity at knee No rigid deformity of the foot and ankle Other knee normal	Prevent the knee from buckling during single leg stance Permit knee flexion during swing	some comment needed since most surgeons are afraid to prescribe this
Quadriceps power Grade III or less Recurvatum deformity at knee that is passively correctable No rigid deformity of the foot and ankle Other knee normal	Prevent the knee from buckling during single leg stance Prevent the recurvatum deformity from progressing Permit knee flexion during swing	Lehneis modification of the floor reaction orthosis (high popliteal trim line and suprapatellar extension)
Quadriceps power Grade III or less of both knees No deformity at knee No rigid deformity of the foot and ankle	Prevent the knees from buckling during single leg stance Permit knee flexion during swing on one side	Thermoplastic floor reaction orthosis on stronger limb and knee-ankle-foot orthosis with drop-lock knee joint on weaker limb
Power of hip muscles less than Grade III Quadriceps power Grade III or less No flexion deformity at knee No rigid deformity of the foot and ankle Other hip normal	Prevent hip instability Prevent the knee buckling during single leg stance	Knee-ankle-foot orthosis with thermoplastic ischial bearing quadrilateral socket, double irons and drop-lock knee joint
Power of muscles of both hips less than Grade III Quadriceps power Grade III or less No flexion deformity at knees No rigid deformity of the feet and ankles	Prevent instability of both hips Prevent the knees from buckling during single leg stance	Bilateral knee-ankle-foot orthosis with thermoplastic ischial bearing quadrilateral socket, double irons and Swiss knee joints (bail locks)

Preventing or Correcting Deformities of the Lower Limb

General principles

Once a child is walking confidently (or if he or she presents initially as a walker), one should focus on preventing and correcting deformities.

Preventing deformities that develop with growth

Since deformities that develop over time are often due to muscle imbalance across the axes of movement of joints it is important that muscle rebalance is restored. Since accurate documentation of power of all muscle groups acting on each joint is imperative good manual muscle testing skills need to be relearned.

Restoration of muscle balance can be achieved if a muscle of adequate strength from the stronger side of the joint axis can be spared for transfer to the weaker side. It is important to be aware that a muscle usually loses one full grade when transferred. Therefore, to be functionally useful a grade of at least IV is necessary.

In situations where a muscle of Grade V of IV power is not available for transfer a Grade III muscle may be transferred; while such a transfer will be unable to provide useful active function after transfer, it may still be effective in preventing deformity by balancing forces about the joint axis.

Correcting established deformities

The principles of deformity correction in polio are:

- Release contracted soft tissues (tendons, fascia and rarely, joint capsules) contributing to the deformity
- Manage residual deformities following soft tissue release by non-operative means (traction, serial casting, wedging of casts)
- Correct residual deformity by bony procedures that shorten the skeleton (osteotomies, arthrodesis) to correct deformities not amenable to non-operative methods of treatment
- In addition, always restore muscle balance by tendon transfers (to redirect a deforming force into a corrective force) or tenotomy (to de-function a deforming force) even if the deformity can be corrected without surgery on the tendons. If the muscle imbalance is not corrected the deformity may recur or a fresh deformity may develop at the proximal joint.

Preventing recurrence of deformity following adequate correction

The strategy for preventing recurrence of deformity is to restore muscle power balance across the axis of the joint as outlined above – which is exactly the same as that employed to prevent deformities.

Tendon transfer

A note on terminology

During the era of rampant poliomyelitis, the terms “tendon transfer” and “muscle transfer” were used synonymously. Since then, the free transfer of muscles together with their neurovascular connections has been introduced. Hence, the terms “tendon transfer” and “muscle transfer” should now be used separately and specifically.

The basic principle of a tendon transfer

Tendon transfer surgery may be performed to improve function or to rebalance forces that may lead to deformities in growing bones. The tendon of a muscle (whose function can be spared by having another muscle to substitute for it, or by an arthrodesis making the function unnecessary) is moved to a different position where it can help another weakened or totally paralyzed muscle. For example, the tendon of the tibialis posterior muscle could be moved to the dorsum of the foot to help a weakened tibialis anterior muscle. A prior subtalar arthrodesis would need to be done so that the foot does not develop a valgus deformity.

Factors to be considered while planning and performing a tendon transfer

- Before a muscle tendon is moved, there must be an adequate range of motion in the joint. A tendon transfer does NOT increase the range of motion of the joint.
- A muscle usually loses one full grade of strength when transferred. Therefore, for a transferred muscle to be functionally useful a grade of at least 4, before the operation, is necessary. However, a grade 3 muscle, while unable to provide a useful function after transfer, may be effective in preventing deformity by better balancing forces about a foot or hand.
- The tendon must be properly positioned so that the pull of the muscle in its new direction is as straight as possible. If this is not done, and there is a large angle, over time as the muscle pulls, the tissues will stretch to the point to bring the tendon into line but it is now no longer at the correct tension.
- Just how tightly the tendon is stretched and anchored to the new attachment point will determine the strength of the transfer. Optimal tension is important as a slack tendon or a very taut tendon may both weaken the transferred muscle by shifting its location either way on the Blix curve.
- The strength of a muscle is proportional to its cross sectional area. Hence the cross-sectional area of the muscle chosen for transfer should roughly match the cross-section of the paralyzed muscle prior to paralysis. A thin muscle can never do the job of a muscle that was two times bigger before paralysis. This is the reason why tendon transfers to substitute for a paralyzed gastroc-soleus are never very effective.

In-Phase and Out-of-Phase tendon transfers (Synergy)

In the hand the two phases of function are grasp and release while the phases of function in the lower limb are the swing phase and the stance phase of gait. When the tendon of a muscle is transferred to replace a paralyzed muscle in the same phase (in-phase transfer) it needs very little re-education. However, when the transfer of a tendon is performed to restore function of a paralyzed muscle in the opposite phase (out-of-phase transfer) muscle re-education may be needed. However, most tendon transfers that have been well considered and skillfully carried out require remarkably little effort, and often formal therapy is not needed for them to quickly function automatically at their new task. Robert Beasley whose focus was entirely on tendon transfers in the hand stated that "the difficulty in re-educating a transferred muscle is inversely proportional to the usefulness of the new arrangement". Beasley also pointed out the necessity of sensory feedback for the development of automatic function following a tendon transfer. "The handwriting of a person with a sensory deficit who is then blindfolded becomes illegible, as both tactile and visible monitoring links in the muscle control system have been lost"

In polio patients, the majority of tendon transfers are done in the lower extremity are usually out of visible monitoring, and often the functional change is not obvious. Transfer of the external oblique muscle to the greater trochanter, which was shown to be an "out-of-phase" transfer by gait analysis, did not activate during gait and did not decrease abductor lurch. (see Watts, Joseph & Sabharwal The Hip in Poliomyelitis)

Tendon transfers such as the tibialis posterior and peroneal muscle forward to the dorsum of the foot or the tibialis anterior to os calcis are out-of-phase transfers and these patients are likely to require more specific training.

Preventing and correcting deformities of the foot:

Descriptions of foot deformities are confusing, in part because of the many differences in the terms that are used to describe them– inversion/eversion, pronation / supination, varus/valgus. Some of the terms that are used describe motions i.e. inversion/eversion, while some describe positions i.e. varus/valgus. Things may be further complicated because there may be a combination of deformities such as equinovarus.

Equinus

Aim of treatment

- Enable to placement of the heel on the floor while standing and walking
- Enable squatting on the floor with the heel on the ground

Treatment options for correcting fixed equinus deformity:

- Stretching exercises in a young child if the deformity is mild
- Serial casting if the deformity is mild or moderate in a child under ten years of age
- Achilles tendon lengthening in the older child and adult with severe deformity
- Posterior capsulotomy of the ankle joint
- Serial wedging of casts for residual deformity
- Supramalleolar dorsiflexion (anterior closing wedge) osteotomy of the distal tibia if the dome of the talus is flattened
- Lambrinudi type of triple arthrodesis (the foot is dorsiflexed around the plantarflexed talus) if hindfoot stabilization is also warranted in a skeletally mature individual

Treatment options for preventing recurrence:

- Ankle-foot orthosis
- Tendon transfer to restore muscle balance

If the ankle is not sufficiently mobile for the foot to reach the neutral position, ***orthoses and muscle transfers will not work***.

Effect on the subtler joint of equinus at the ankle:

If the subtalar joint is unstable, equinus may be masked by heel eversion and mid-foot valgus. Examination of ankle motion, should be done by first planter flexing the ankle fully, and then moving the hind-foot into inversion. With the foot held in this position, the ankle is tested for any limitation in dorsi-flexion. For the reasons described above, if equinus is being corrected by serial casting the deformity must be corrected while holding the hindfoot in inversion. If this is not done a false correction can occur through the subtalar and mid-tarsal joints.

Effect on the knee of equinus at the ankle:

It is important to remember that some degree of equinus contracture may mechanically help to stabilize the knee by forcing the tibia back at heel strike and thus the knee into hyperextension during stance phase, in the same manner as a Floor Reaction AFO (Pre-Tibial AFO) does. **For this reason, the equinus deformity must NOT be corrected if the power of the quadriceps power is Grade II or poorer** as lengthening the tendoachilles may take away the child's ability to walk without an orthosis.

Where the quadriceps strength is Grade III or better, the tendoachilles may be safely lengthened.

The difficulty arises when the child locks the knee with a combination of ankle plantar-flexors and hip extensors. There is no easy answer to the difficulty of analyzing this problem except to weigh the strength of the existing muscles against the severity of equinus and if the decision is made to correct the equinus, one should proceed cautiously, possibly starting with serial casts (even if a child is older than 10 years).

If the child is an orthosis wearer and there is an equinus contracture, the contracture can be corrected for comfortable brace wearing, remembering always that there is a surprising amount of functional improvement with time in almost any given child, so one should not burn a bridge which may be useful later on. Equinus need not be overcorrected. The foot is better left in neutral plantar flexion to increase stride length.

Foot drop (syn. Drop foot)

Aims of treatment

- Abolish the high-stepping gait
- Facilitate clearance of the ground during swing
- Restore ability to actively dorsiflex the ankle, if possible, by restoring muscle balance across the ankle axis

Treatment options for correcting foot drop

- Ankle-foot orthosis as an interim measure in young child while waiting for a tendon transfer
- Ankle-foot orthosis as a long-term option if there are no suitable tendons available for transfer
- Transfer of the tibialis posterior to the dorsum of the foot
- Transfer of the peroneus longus to the dorsum of the foot
- Transfer of the extensor hallucis longus to the neck of the first metatarsal with arthrodesis or tenodesis of the inter-phalangeal joint of the great toe (Jones transfer)
- Transfer of the long toe extensors to the center of the dorsum of the foot

Hind-foot valgus

Aim of treatment

- Realign the hindfoot
- Restore muscle balance across the subtalar joint

Treatment options for correcting hind-foot valgus

- Extra-articular fusion of the subtalar joint by the Grice-Green or the Dennyson and Fulford technique and transfer of the peroneus longus tendon
- Triple fusion and tenotomy of the peronei in the adolescent

Equino-varus

Aim of treatment

- Enable the child to walk with the foot flat on the ground (not on the lateral border of the foot with the heel off the ground)
- Restore muscle balance across the ankle and the subtalar joint

Treatment options for correcting equino-varus deformity

- Extra-articular subtalar fusion by the Grice-Green or the Dennyson or the Fulford technique and transfer of the tibialis posterior tendon to the center of the dorsum of the foot
- Triple arthrodesis in the adolescent or adult with tenotomy or transfer of the tibialis posterior

Calcaneus

Calcaneus deformity results from absent or a weak ankle plantar flexor (triceps surae) in the presence of functioning ankle dorsiflexors and this is one deformity that tends to progress and become more severe over time.

This deformity is particularly difficult to treat effectively with tendon transfers as no muscle in the leg can match the power of the triceps surae. This is because the cross-sectional area of the triceps surae exceeds the sum total of cross sectional area of all other muscles in the leg put together.

Often the deformity may be associated with a valgus instability of the subtalar joint due to muscle imbalance across the subtalar axis resulting in a calcaneo-valgus deformity.

Aims of treatment

- Reduce the risk of progression of the deformity by an early tendon transfer
- Reduce the calcaneal hitch while walking
- Improve the muscle balance

Treatment options for correcting calcaneus deformity

- Transfer of the tibialis posterior and the peronei to the calcaneus with extra-articular subtalar fusion in a child with Grade V power in the muscles being transferred
- Westin tenodesis of the tendoachilles to the fibula with ankle in 10 degrees of plantar-flexion in a young child with no muscles of sufficient strength to transfer*
- Triple fusion (Elmslie-Chomley technique)with transfer or tenotomy of the tibialis anterior

**: When done before the age of 11 years, equinus may develop but this can be managed by lengthening the tenodesis.*

Cavus

A cavus deformity with an excessively high arch may occur in isolation or in association with an equinus deformity (equino-cavus), a calcaneus deformity (calcaneo-cavus). This is the result of tightness of the plantar fascia due to fibrosis, or an imbalance of muscles. In the very young, less than 3 years of age, stretching exercises and serial casting may improve the deformity. In the majority of instances surgery is needed.

Aim of treatment

- To distribute the pressure under the foot over a larger area

Treatment options for correcting cavus

- Release of the plantar fascia
- Mid-tarsal wedge resection

Dorsal bunion

A dorsal bunion results from a strong and active tibialis anterior muscle with a weak or paralyzed peroneus longus muscle. This is commonly accompanied by a supinated position of the foot.

Aim of treatment

- Correct the deformity to reduce friction in footwear
- Restore muscle balance across the first metatarso-phalangeal joint axis

Treatment options for correcting dorsal bunion

- Transfer tibialis anterior to the center of the dorsum of the foot
- Transfer flexor hallucis longus to the neck of the first metatarsal with arthrodesis or tenodesis of the inter-phalangeal joint of the great toe (Reverse Jones procedure)

Preventing and correcting deformities of the knee

Flexion deformity

Aim of treatment

- Correct the deformity and facilitate walking without the need for an orthosis where possible
- Correct the deformity to facilitate fitting an orthosis to enable walking

Treatment options for correcting flexion deformity of the knee

- Serial casting and wedging in young children with mild deformity or if there is residual deformity following soft tissue release in older children
- Guided growth with two 8-plates placed anteriorly across the distal femoral growth plate on either side of the patella may be tried in the young child with severe deformity
- Release of the ilio-tibial band and hamstring tendons
- Skeletal traction to correct residual deformity after soft tissue release surgery*
- Supracondylar extension osteotomy in the skeletally mature person§

**: In order to prevent posterior subluxation of the tibia two Steinmann pins should be inserted into the tibia; one in the proximal tibia for forward traction on the tibia and one in the lower tibia for longitudinal traction.*
§: If the quadriceps are paralyzed the wedge resected from the anterior aspect of the femur should be large enough to create hyperextension of 10 degrees. This will provide sufficient stability to facilitate walking without bracing the knee.

Back-knee deformity (syn. genu recurvatum)

Genu recurvatum in children is progressive and once it becomes severe treatment is difficult. Bracing should be instituted in the young child with genu recurvatum

In the older patient a mild degree of recurvatum is beneficial if the quadriceps are weak; **in this situation the deformity should not be corrected.**

If the deformity is greater than 10 degrees lateral radiographs of the knee should be obtained in order to determine if the deformity is predominantly in the femur or tibia to plan appropriate treatment.

Aim of treatment

- Prevent progression of deformity in the young child
- Correct the deformity while retaining stability of the knee

Treatment options for correcting genu recurvatum

- Knee ankle-foot orthosis in the young child
- Lehneis modification of the floor-reaction orthosis in the older child
- Femoral supracondylar flexion osteotomy in the skeletally mature person if the deformity is in the femur*
- Proximal tibial flexion osteotomy in the skeletally mature person if the deformity is in the tibia

**: If the quadriceps are weak, under-correct the deformity and leave 10 degrees of residual recurvatum for knee stability.*

Genu varum and valgum

Varus and valgus deformities at the knee can lead to degenerative arthritis in the long term. Thus, varus and valgus deformities at the knee must also be addressed. Bony deformities require osteotomies, but any soft tissue contractures must be corrected first. Varus or valgus soft tissue instabilities generally require a KAFO after surgery.

Aim of treatment

- Prevent progression of deformity and degenerative arthritis

Treatment options for correcting genu varum or valgum

- Guided growth in the child with sufficient growth remaining
- Corrective osteotomy of the femur or tibia as required

Rotary Subluxation of the Knee

A tight tensor fascialata will create a knee flexion contracture eventually. After the knee flexion becomes fixed, the lateral force ends in a lateral rotation of the tibia on the femur, i.e. a lateral rotary subluxation of the knee. With time, the knee joint surfaces remodel to accommodate the lateral rotation, and if left untreated the deformity becomes permanent.

Aim of treatment

- Prevent progression of deformity

Treatment options for correcting rotary subluxation of the knee

- Release of the contracted tensor fascia lata (Yount release)

Preventing and correcting deformities of the hip

Flexion deformity

Aim of treatment

- Correct the flexion deformity in any patient with a potential to walk
- Reduce the lumbar lordosis

Treatment options for correcting flexion deformity of the hip

- Release of the contracted tensor fascia lata, sartorius, rectus femoris (Soutter release)
- Serial casting for mild or moderate residual deformity following soft tissue release in young children
- Skeletal traction for mild or moderate residual deformity following soft tissue release in adolescents and adults*
- Extension osteotomy of the proximal femur to correct severe residual deformity following soft tissue release

**: The patient must be monitored for hypertension which may develop during traction to correct hip and knee flexion contractures.*

Release of the anterior capsule of the hip has been advocated in the past but we do not recommend it for fear of producing hip instability.

Abduction deformity

Aim of treatment
• Correct the abduction deformity in any patient with a potential to walk • Reduce the pelvic obliquity which may be contributing to instability of the contralateral hip
Treatment options for correcting abduction deformity of the hip
• Release of the contracted tensor fascia lata and the gluteal muscles from the iliac crest and let the muscles slide distally*

**: If the gluteal muscles are paralyzed the abduction deformity must be under-corrected as a mild residual abduction contracture will prevent a Trendelenburg gait*

Hip instability

Although a great deal has been written about regaining hip joint stability after poliomyelitis, the need for such surgery is questionable. As in the treatment of the unstable hip in myelodysplasia, a dislocated hip may not be a significant impairment to function. While one attempt may be justified, multiple surgical attempts to regain muscle balance can result in hip stiffness. Hip stiffness can be very disabling in cultures where floor sitting is an important activity of daily living— the very cultures where poliomyelitis is more common.

Aim of treatment
• Correct pelvic obliquity that maybe contributing to hip instability • Correct the structural factors in the proximal femur and acetabulum that may be contributing to hip instability (e.g. coxa valga, acetabular dysplasia) • Correct muscle imbalance that may be contributing to hip instability
Treatment options for correcting hip instability
• Release abduction contracture of opposite hip, if present • Correct or compensate for shortening of the opposite limb, if present, by limb-length equalization surgery or shoe raise • Proximal femoral varus osteotomy to correct coxa valga • Acetabuloplasty or shelf procedure to reduce acetabular dysplasia • Iliopsoas transfer to the greater trochanter (Mustard transfer)

The dangling leg

Where a child has a flail leg and normal upper extremities, trunk and a normal contralateral leg, he or she may learn to get about remarkably well by using crutches or a stick and dangling the affected limb. Leaving the situation as it is has the virtue of economy of medical effort but may not be in the child's best interest. Often such a child can be fitted with an appropriate KAFO and shoe lift following deformity correction, and then learn to walk without crutches. This has the advantage of freeing up his hands for more useful functions, as well as stimulating better growth in length of the flail limb. The bones will become more robust and may result in fewer fractures. The change from crutches and a dangling limb to an orthosis usually requires a period of crutch use and as well as the brace. This will appear to the child and the parents as a step backward. This difficult transition may require clever persuasion.

Limb-length inequality

How the leg length discrepancy is managed depends on how great the difference is, or if the patient is still growing and how great the difference is predicted to be at maturity. The alternatives are to lengthen the short side or shorten the long side or both.

Anticipated limb length inequality at skeletal maturity	Maturity of the patient	Treatment option
• 2 cm	• Skeletally immature	• No intervention*
	• Skeletally mature	• No intervention*
• 2 cm – 5 cm	• Skeletally immature with sufficient growth remaining	• Epiphyseodesis of the distal femoral and / or the proximal tibial epiphysis
	• Skeletally mature	• Limb lengthening or shorten the longer limb
• Greater than 5 cm	• Skeletally immature	• Limb lengthening or combination of epiphyseodesis of longer limb and lengthening of the shorter limb
	• Skeletally mature	• Limb lengthening

**The presence of angular or rotational skeletal deformities along with limb shortening may require a modified approach.*

The technique of limb lengthening currently used is based on the principles of Ilizarov's distraction osteogenesis. An external fixator is applied and the bone is divided and distraction at the rate of 1 mm per day is begun after 5 – 10 days depending on the age of the patient (5 days for young children and 10 days for adolescents and adults). The delay in commencing distraction permits early healing and it is the immature callus that is lengthened. After the requisite amount of lengthening has been achieved the external fixator is left in place for a further period of time to permit the lengthened callus to consolidate and differentiate into a cortex and medulla. The time required for consolidation is approximately one month for each centimeter of length gained.

The type of external fixator used depends upon the anatomy of the bone being lengthened, implant availability and the surgeon's preference. Ring fixators using fine wires, popularized by Ilizarov, have virtue in the region of the tibia but are more complex to use in around the femur. Unilateral fixators with stout pins are easier to apply on the femur but because the pins are unilateral the fixation may not be as structurally stable.

If appropriate implants and surgical expertise is available, lengthening over an intra-medullary nail or heavy k-wire may decrease the time in the external fixator and minimize the risk of re-fracture or bending of the lengthening regenerate following fixator removal. However, such an approach does increase the possibility of a deep infection due to the presence of an intramedullary device with an overlying external fixator with possible pin site drainage.

It is important to be aware that complications of lengthening are frequent. These include delayed union or nonunion, poor bone regenerate, infection of the bone and pin tract infections. Antero-posterior subluxation of the tibia on the femur at the knee can be a common problem when the femur is lengthened. Dislocation of the proximal joint of the bone undergoing lengthening is also a risk. Fractures of the bone after lengthening as well as joint stiffness and nerve injury may also be encountered. In the light of these potential complications lengthening of bones should not be undertaken lightly.

Surgery for comfortable brace wearing:

It is wise to remember that in most children some spontaneous improvement in function occurs with time. Some children whom one thinks will not be able to walk free of an orthosis do so. Allow the child to prove that he or she will always be an orthosis wearer. If the child proves that he / she is always going to have to wear an orthosis, then procedures should be aimed at making the brace wearing comfortable. Examples of procedures that can significantly improve brace comfort include:

i) Correction of equinus deformity

ii) Stabilization of the subtalar joint in the neutral position in children with a valgus hind foot so that the medial malleolus does not become abraded by the medial surface of the orthosis

iii) Derotation of an externally rotated tibia

iv) Tenodesis of the Achilles tendon to the fibula in the presence of calcaneus deformity without any functioning muscle to transfer.

Surgery to relieve a lifetime dependency on an orthosis or to reduce the extent of bracing:

Once the person is walking with confidence, and deformities have been corrected, one may ask, "Can the patient be made brace-free or can the bracing be decreased?"

This is a controversial issue. Surgeons are more likely to favor the idea of a patient undergoing a simple operation to obviate the need for a lifetime of bracing. Those who are less sanguine about surgery (which may include the patient, the family or any of the other care givers) may decline such a choice. The economics in the local situation will determine which route is more cost-effective (i.e. a single operation versus a lifetime of brace fabrication and repairs).

Clinical situation			Extent of bracing required	Strategy for reducing bracing
Knee	Hip	Ankle		
Skeletally immature child with Quadriceps paralysis + Mild flexion deformity	Strong hip extensors	Strong ankle plantar-flexor	KAFO	Correct knee flexion deformity and apply AFO holding the ankle in mild plantar-flexion Reduce to AFO
Skeletally mature person with Quadriceps paralysis + Mild flexion deformity	Strong hip extensors	Strong ankle plantar-flexor	KAFO	Over-correct knee flexion deformity and create mild hyper-extension by a supracondylar extension osteotomy Brace can be discarded
Skeletally mature person with Quadriceps paralysis& no flexion deformity of the knee	Strong hip extensors	Weak ankle plantar-flexor	KAFO	Fuse the ankle in mild equinus* Brace can be discarded

**: To demonstrate the result of ankle fusion in this situation, fabricate an AFO, which fixes the ankle in slight equinus or apply a short-leg cast. The degree of equinus can be adjusted to find an optimal position*

Correct upper limb problems

Once a person is walking or if it has been decided that he or she will be a permanent sitter, attention should be turned to the upper limb.

The frequency of upper extremity involvement in one or both upper limbs among those affected by paralytic poliomyelitis is considered to be low (approximately 10%) although in the Tajikistan epidemic of 2014, the frequency of upper limb involvement was 29%.

The Shoulder

In the past, many surgeons specializing in the upper extremity have stated that the shoulder is just a joint for getting the hand where it is needed. Observing people who have had poliomyelitis show this statement to be clearly untrue. The ability to adduct the upper arm against the chest wall provides many with active power to grasp objects. Some can manipulate a crutch sufficiently well to allow them to walk even though they have no hand function to grasp the crutch with. Shoulder stability is an important factor in order to use the elbow flexor muscles that cross both joints (i.e. the biceps). Following a shoulder fusion, many people find they have much better use of their hands and elbows; for this reason, we prefer to consider the shoulder first.

While tendon transfers around the shoulder suggested by Saha give an excellent theoretical basis for understanding shoulder function, the transfers themselves have proven to be unreliable in patients with poliomyelitis. On the other hand, arthrodesis of the proximal humerus to the glenoid has proved to be an excellent procedure. Provided that the levator scapuli, the serratus anterior and the medial scapular muscles are strong, a shoulder arthrodesis can be very beneficial.

Our experience has concurred with that of Makin, in that the shoulder should be fused early (between the ages of 6-8 years). The proximal humeral physis should be protected since it provides 80% of the growth of the humerus. This is best done by a cruciate incision in the articular cartilage, then peeling the cartilage away from the underlying bone (like peeling the skin off an orange). Fixation is by threaded Steinmann pins, which are removed at 6-12 weeks. The chance of injury to the proximal humeral physis is minimal with this technique. In older patients the A-O technique of plate fixation has proved to be excellent.

Earlier experience with the fusion of shoulders in children demonstrated a gradual loss of abduction over the years after fusion, prompting surgeons to recommend that the shoulder in children with poliomyelitis be fused in 60 + degrees of abduction. This problem was encountered when fusion was done without internal fixation for fear of damaging the proximal humeral physis. With the advent of the use of internal fixation, this has not been a problem so the usually advocated post-operative position is preferred.

It is strongly advised to decide whether a Steindler flexorplasty (see below) will be necessary before the decision for shoulder fusion is made. Attempting a Steindler procedure with absence of shoulder external rotation after a shoulder fusion makes the Steindler operation markedly more difficult.

The Elbow

Lack of elbow flexor strength is the usual problem. The function of a normal hand is grossly limited if active elbow flexion is absent.

Aim of treatment
• Restore the power of active elbow flexion
Treatment options for restoring active elbow flexion
• Steindler flexorplasty(transferring the origin of the wrist flexors or extensors or both proximally) • Triceps transfer (Contraindicated if the patient requires crutches for walking *)

**: While the transfer of the triceps anteriorly to the biceps insertion can be very useful in increasing flexion strength at the elbow, crutch stability needs the triceps function, as does wheelchair propulsion. So an anterior transfer of the triceps may lead to the inability to walk because crutches can't be used, or if the child is an obligate wheelchair user, that function can be lost.*

Transfer of the pectoralis major; or transfer of the latissimus dorsi on its neurovascular pedicle are more complex procedures and not always available in regions where children with AFP are found.

The Forearm

The common problems seen are extreme position of the forearm either in supination or pronation.

Before undertaking the correction of a forearm deformity, it is important to assess the cultural setting of the patient. In a culture where implements are used for eating (i.e. knife and fork) eating is done with the hand/forearm pronated. In those cultures where the hand is used as the primary tool of eating, without implements, it is done with the hand/forearm in supination. Writing and keyboard activity are primarily done with the forearm in pronation.

Supination contracture

Aim of treatment
• Correct the contracture and restore power of pronation
• Treatment options for correcting supination contracture of the forearm
• Release of contracture* followed by Zancolli operation (re-routing of the biceps tendon around the radius)§

**: The contracture is best treated by total release of the interosseous membrane (approached dorsally). Following release, the forearm is held in the corrected position in a cast for 6-8 weeks and the correction is then maintained by physical therapy. Re-routing of the biceps is done only after this.*
§: The Zancolli procedure should only be used where there is an additional supinator other than the biceps or else a pronation contracture can result. In the older child, or an adult, it is sometimes necessary to carry out derotation osteotomies of the forearm to correct the supination deformity.

The Hand

Opposition of the thumb is not only important in grasping objects, such a food or drink, but is of major importance in the use of crutches and for propelling a wheelchair therefore important for the patient's mobility.

Aim of treatment
• Correct adduction contracture of the thumb • Restore power of active opposition if possible • Fuse thumb in opposition if tendon transfer not feasible or fails
Treatment options for restoring opposition of the thumb
• Release of adduction contracture • Opponensplasty (e.g. transfer of the flexor digitorum superficialis of the ring finger) • Inter-metatarsal graft between first and second metatarsals with the thumb in a position of opposition

In crutch walkers, the procedure should be delayed until the patient is able to cooperate, as there is a real concern that the transfer will stretch out. The patient and the caretakers need to understand that crutches cannot be used for at least 6 weeks after surgery and then the transfer needs to be protected for a further 3 months by a splint. If the transfer stretches out with crutch use and becomes ineffective opposition may be maintained with an iliac strut graft between the first and second metacarpals.

The same concern should be exercised in patients who are obligate wheelchair users where the thumb may be utilized to rotate the wheel and can stretch out a transfer.

A wrist fusion may be useful in order to free up a muscle and its tendon for transfer to gain improved hand function when there is more extensive paralysis of the hand.

Correcting spinal problems

Incidence

The estimates of the incidence of scoliosis following poliomyelitis are often imprecise since they are based on physical examination rather than surveys by x-ray. In the Tajikistan poliomyelitis outbreak of 2010, of the 360 people personally (HW) evaluated by physical examination there were 39 who had scoliosis (11%). All but two were under 10 years of age at the time they contracted poliomyelitis. Of the children who contracted poliomyelitis before the age of 10 years 18% had trunk involvement. Less than 1% of those who contracted poliomyelitis after the age of 10 years demonstrated trunk involvement.

Types of scoliosis

Scoliosis in poliomyelitis is generally seen in two groups of children:

1. The first are young children who suffer extensive paralysis of the trunk muscles and develop scoliosis very early, commonly within two or three years of the paralytic episode. The scoliosis in these children tends to be in the thoracic spine and the respiratory impairment often ensues. In regions with limited medical resources these children commonly die in early childhood.
2. The second are children in whom scoliosis develops gradually in later childhood. The scoliosis is usually in the lumbar region and the spinal curve may compromise the ability to walk or sit.

Problems of management

The management of scoliosis in poliomyelitis is very different from that of idiopathic scoliosis.

- The alignment and mobility of the spine can influence the ability to walk.
- Loss of lumbar lordosis following spine surgery can be a major impairment to walking and sitting, if the hip extensors are weak since there will be no way for the child to lean back sufficiently to get the mass of the trunk posterior to the hip joints.

- A supple lumbar spine may be necessary not only for forward movement but also lateral "balance". This may be insignificant in a crutch-free and brace-free child, but it may be catastrophic in a marginal household walker. Fusing the lumbar spine may decrease (or totally prevent) the patient's ability to walk, whether or not the pelvis is included in the spinal instrumentation. Parents not warned of this potential difficulty will be justifiably upset if their child stops walking after a spine fusion.
- A severe lumbar curve can be a major difficulty in walking due to the resulting apparent leg length inequality. Additionally, if a child's curve is very supple, he may need to expend an extra effort to stretch out the spine before the push on the crutch straightens the spine sufficiently to allow clearance during swing phase.
- Children with paralytic scoliosis often use their curve, particularly the kyphotic and lordotic elements to balance their trunks. The great majority of children in non-Western countries sit on the floor. Following straightening the spine surgically they are inclined to fall over like a spent top if they sit on the floor. Fortunately, this is usually only temporary. Sitting in a chair corrects the problem but that solution may not be popular in a culture where socialization takes place at carpet level. The parents should be warned accordingly.

Examination of scoliosis associated with poliomyelitis

The physical examination of a child with scoliosis following poliomyelitis should not focus on the spine alone but should include a complete manual muscle examination and hip examination for asymmetric hip abduction contracture as surgical release of this may be all that is needed to allow the spine to straighten. Antero-posterior and lateral radiographs should be taken with the patient sitting unsupported.

Role of bracing in the treatment of children with scoliosis due to poliomyelitis

As a general rule, there is little role for bracing in the treatment of children with scoliosis due to poliomyelitis. Bracing a lumbar curve often makes walking impossible. Bracing a thoracic curve when the child has no muscles to withdraw from the pressures of an orthosis may lead to sores and further restrict respiration.

Management of children under eight years of age

Children with early onset scoliosis who have a severe curve are very difficult to manage. Spinal surgery is risky because of the severe pulmonary limitations, and especially so if undertaken in facilities with limited resources. The use of "growing rods" is fraught with complications in even the best of facilities.

Management of children between eight years of age and puberty

The spines of children under 14 years from this second group tend to be much more flexible than those seen in idiopathic scoliosis. Thereafter, the curves tend to become rigid quickly. Consequently, an increasing curve seen on upright films, which would ordinarily signal the need for surgery in a child with idiopathic scoliosis, can often be ignored temporarily in younger children with poliomyelitis. The indication for surgery is not "progression alone", but stiffening of a progressing curve noted on bending radiographs. For an example, an 8-year-old child with a curve which has progressed to 40° but which bends down to 20° may be seen to progress to 80°, over the next four years, while the bending film still shows the curve reducing to 20°. Surgery delayed until age 12 years, will result in a curve no worse than if it had been fused at age 8 years, yet the child will be taller and the need for extendable internal fixation with its concomitant complications can be avoided.

Adequate correction of lumbar scoliosis is necessary to correct the pelvic obliquity, leg length difference and the uncovering of the hip joint. It is very important to maintain lumbar lordosis if gluteus maximus muscles are weak so that the patient can lean backward enough to allow gravity to extend the hips.

In severe cases, pre-operative correction using halo-gravity or halo-femoral traction may be helpful. The technique of the fusion depends on the facilities available to the surgeon. Lumbar curves can be corrected well with anterior instrumentation reinforced with a secondary posterior fusion or with posteriorly based segmental instrumentation with judicious periapical osteotomies to improve curve flexibility. If care is taken during surgery to adequately de-rotate the lumbar spine, the risk of increasing the kyphosis can be minimized. While currently, most surgeons use pedicle fixation in scoliosis surgery there has been limited experience in its use for poliomyelitis.

Timing of scoliosis surgery in relation to lower extremity surgery

If an older, non-walking, child has a severe scoliosis when first seen, it is our practice to fuse the spine first, before doing the lower limb releases required for standing. This is based on the observation that getting such an older child up and walking after lower limb releases and bracing may take many months, during which time the curve is worsening. Furthermore, if the leg procedures are performed first, the long "learning-to-walk" process then has to be redone after the spinal surgery.

The Role of Physiotherapy:

Physical Therapy Evaluation

To plan an appropriate physical therapy evaluation and intervention the therapist needs to understand what activities are important to the patient and to assess whether alleviation of various impairments will improve the patient's performance of those activities.

The first item to consider is: Why has the patient come to see you?

The ICF (International Classification of Functioning, Disability and Health) can be a useful guide to the evaluation of and intervention with our patients.

Below are examples of using the ICF to identify common activity limitations and impairments seen frequently in patients who have polio.

Activities of concern for patients with polio:

1. Walking
2. Using a wheelchair
3. Lifting a child or a heavy object

Impairments of concern for patients with polio:

1. Contractures or lack of joint excursion or range of motion of a specific joint
2. Excessive joint motion and/or joint instability
3. Weakness or lack of strength in specific muscles

A thorough evaluation of patients with polio includes the following:

1. Activity or function
2. Gait
3. Range of Motion
4. Muscle Strength

Two common assessments performed by physical therapists in order to determine the nature of a patient's impairments are:

I) Assessment of range of motion (Goniometry)

II) Assessment of muscle strength (Manual Muscle Testing or Dynamometry)

Evaluation of Function

Areas to be evaluated and potential assessments

I. Balance: Can the patient stand without support? Can the patient sit without support? If not what is the specific area of weakness or contracture causing the inability?

II. Various types of activities that we all participate in

These are the primary categories of activities in the International Classification of Functioning, Disability and Health2002 Version also called the ICF.

1. Learning and Applying Knowledge
2. General Tasks and Demands
3. Communication
4. Mobility
5. Self-Care
6. Domestic Life
7. Interpersonal Interactions and Relationships
8. Major Life Areas
9. Community, Social and Civic Life

Examples of activities in each of these categories that would be affected if a person has lower extremity muscle weakness

4. Mobility
    - Transferring oneself
    - Lifting and carrying objects
    - Walking
    - Moving around using equipment

5. Self-Care
    - Dressing
    - Toileting

6. Domestic Life
   Preparing meals
   Doing housework

7. Interpersonal Interactions and Relationships
   Intimate relationships

8. Major Life Areas
   School education
   Work and employment
   Economic self-sufficiency

9. Community, Social and Civic Life
   Recreation and leisure

All patients should have an observational gait assessment. If the patient uses a wheelchair or other mobility device the function and fit of this equipment should be assessed. Gait speed should be evaluated and can be done with a stopwatch or timer over a measured distance.

In some settings formal assessments such as the following may be used:

6 Minute Walk Test
The Timed Up and Go
Sit and Reach
Falls Risk

Intervention
- Post-op
- Chronic
- Gait Training
- Equipment
  - Orthoses
  - Walkers
  - Crutches
  - Wheelchairs

Follow-up and re-evaluation

What Services Do Survivors of Polio Require

We are talking about people with chronic polio meaning that they had their acute infection at least 2 to 3 years before this current intervention. This means the paralysis is stable, not changing. Since most people get polio as children we will focus on children's issues. The purposes of a rehabilitation program are to allow people to fulfill their desired roles in life, to allow them to develop into productive members of society and to reduce the healthcare burden. Rehabilitation services may include physical and occupational therapy, training in the use of orthotics and or other assistive devices and orthopedic surgery. It should always include family training since the family is with the person most of the time and they only will have intermittent contact with rehabilitation providers.

Children will have secondary complications related to their growth and the muscle imbalance caused by their paralysis. One very common complication is a Leg Length discrepancy.

Leg Length Discrepancy Interventions

Shoe lift
Crutches or a walker
If caused by contractures at the hip, knee or ankle, surgical contracture releases are possible
Refer to Length Leg Inequality (above) for an extensive discussion of management of this complication.

Contractures are another very common complication. They can interfere with walking and hand use for example. And they may make it difficult for the person to use an orthosis or brace. Children are very susceptible to contracture development again because of their growing muscles and bones. It is easy for strength imbalances to lead to decreased range of motion (ROM), further weakening the already weaker muscle.

Contracture Interventions

- Prevention if possible
- ROM exercises
- Bracing or splinting
- Positioning
- Muscle strengthening of opposing muscles

Some common contractures

- Finger flexion
- Shoulder flexion
- Hip Abduction
- Knee Flexion
- Ankle Plantarflexion

Range of Motion (ROM) exercises

It is very important to do ROM exercises slowly and with adequate support of the joint being stretched. It is easy to overstretch tissues especially in children who are weaker and where there is already a weakened muscle.

Some examples of typical range of motion exercises

Stretching into finger extension

Be sure to stabilize the fingers joints in neutral and extend the hand and wrist with slow steady pressure. Hold the extended position for a count of 10.

Stretching into shoulder extension

Be sure to stabilize the scapula and stretch the shoulder joint forward and upward. The elbow can be flexed if the person is unable to extend the elbow while the shoulder is being moved into extension. Hold the extended position for a count of 10.

Stretching into hip adduction

Be sure to stabilize the pelvis and gently pull the hip into extension and adduction. The tensor fascia lata will often pull the hip into flexion and abduction causing a contracture so that is the primary muscle requiring stretching. Hold the extended adducted position for a count of 10.

Stretching into knee extension

Be sure to stretch by putting your force very close to the knee joint and not subluxating the tibia posteriorly. You want to gently pull the knee into extension by making sure you are stretching the hamstrings pulling out and up, not pushing down on top of the knee. Hold the extended position for a count of 10.

Stretching into ankle dorsiflexion

Be sure you maintain the ankle in neutral. You do not want the foot positioned in either inversion or eversion. You must also be careful that you are pulling the foot into dorsiflexion by stretching the gastrocnemius, soleus tendon from the heel. The entire sole of the foot needs to be supported while the pull is applied to the heel. Hold the dorsiflexed position for a count of 10.

Teaching the family good positioning can be helpful in preventing contracture development.

Muscle strengthening or muscle re-education exercises

Recovery of muscle function and regaining of strength are important areas of focus for physical therapy. One very important lesson that has been learned from people with post-polio syndrome and people who have lived for a long time after contracting polio is that it is very easy for these patients to develop over-use injuries. Based on the information from Beasley about how little residual muscle tissue it takes to function with a grade 3 muscle it is easy to appreciate how additional loss from aging contributes to over use. Therefore it is critical to educate the patient and family about what to expect over the long term. Patients should be taught energy conservation techniques and should be counseled about not over doing manual wheelchair propulsion for example in order to preserve shoulder muscle function. Gaining weight and increasing stress on muscles and joints can compromise function for patients who have had polio. When providing guidance for strength training watch out for excess muscle fatigue. Be sure to consider endurance as well as strengthening exercises. And do not overlook the need to strengthen the trunk and muscles of respiration. Facial muscles may also need strengthening and re-education if the patient has facial paralysis.

Use of Mobility Aids

Many people who use bilateral long leg braces are able to use axillary or Lofstrand or forearm crutches to walk. Initially people may be more comfortable with axillary crutches but they should be encouraged to use Lofstrand crutches as soon as their upper body strength and balance will permit it. Because people with polio will use crutches for a lifetime they are at risk of crutch palsy and shoulder and or wrist overuse injuries. Crutch palsy is a compression injury to the brachial plexus resulting in weakness of the arm and hand muscles. For this reason Lofstrand crutches are a better option since there is no risk of compression of the brachial plexus in the axilla.

Some people with trunk weakness and or scoliosis as well as bilateral leg weakness may require a walker. And some people may initially require a walker and then once they have gained strength and walking experience will be able to move to crutches.

Some patients will polio will require a wheelchair for longer distances as walking just takes too much energy particularly in less accessible communities. And some people will have a level of paralysis that means a wheelchair is their only mobility option. Making sure the wheelchair fits properly is very important both for efficient use and contracture prevention. Providing a child-sized chair is critical for children and the option for the chair to be altered as the child grows is also an important part of long term planning for service providers. The patient and family need to be taught how to clean and maintain the wheelchair so it functions properly. These patients are also at risk for shoulder overuse injuries and it is very important to pay attention to shoulder strength as well as transfer techniques and wheelchair propulsion techniques to try to minimize this. Maintaining a healthy weight and adequate shoulder strength is also critical.

Post-operative interventions

Surgeons will differ in the details of how they will perform a particular surgical procedure. It is imperative to discuss the procedure with the surgeon to ensure that the physiotherapist and surgeon are in tune with the specific plans for surgery and post-operative care.

The recommendations below will need to be modified to comply with the specific demands of the facilities available and the surgeons' preferences. For example, an operation might be done as an out-patient procedure in some regions or as an in-patient procedure in others. A knee flexion release for a mild contracture might be managed by serial casting while a more severe contracture might be managed by a tendon or fascia release while a severe one requires an osteotomy.

To say that "the patient had a release of a hip flexion contracture" doesn't tell you whether just the fibrous tissues anteriorly were divided, or that particular tendons were lengthened or possibly totally divided, or whether the joint capsule was widely opened and therefore vulnerable to hip dislocation post-operatively.

Some procedures require considerable cooperation from the child in doing post-operative exercises. This is particularly important in upper-extremity tendon transfer operations. The age of a patient can make a very big difference in cooperation, making it necessary to delay some surgeries until the child is older.

Common surgical procedures for patients with polio are:

Contracture correction: by surgical release or serial casting (and possibly by serial casting after an initial surgery).

All contracture correction will probably require post-operative physiotherapy. It is important to know what tissues were released and which tissues are vulnerable to excessive stretching exercises post-operatively.

A ***Tenotomy*** is where the tendon is totally divided and the end left loose, or tendon lengthening is where the cut ends are stitched together but more loosely. Such a repair is vulnerable to rupture by excessive post-operative stretching exercise. Sometimes the lengthening is done by making several partial cuts into the substance of the tendon and stretching the tendon. (sometimes called a sliding lengthening). This is done under anesthesia These are usually not vulnerable to post-operative rupture.

Deformity re-alignment: Especially in children, the absence of, or weakening of muscle pull, will change the shape of how the bones and joints grow. If these altered stresses on the bones and joints are not corrected early in the recovery of polio the deformities only get worse. Varus or valgus foot deformities are common as are angular deformities of the tibia and femur. Correction requires wedge shaped segments of bone to be removed and the ends of the divided bones to be fixed together during surgery, as well as post-operative cast or external metal frame fixation until the bone is sufficiently healed and strong. When a cast, or external fixator is first removed the patient's healing bone is particularly vulnerable to fracture from excessive efforts to mobilize an adjacent joint, especially in the first one to 3three months? It is important for the physiotherapist to provide suggestions to keep the person generally active and strong while they recover from surgery in order to make a full recovery easier.

Joint fusion or Arthrodesis: When a joint is very deformed or is unstable because of inadequate muscle strength of the controlling muscles bones of a joint can be fused together by cutting away the articular surfaces and the underlying bony surfaces exposed so that they can grow together. While this can be an advantage to the patient, surrounding joints may now have to make up for the lack of motion. For example, a fusion of the sub-talar joint will put more stress on the adjacent ankle joint and the small joints of the mid-foot.

Spine fusion or arthrodesis: This is a special variant of joint fusion where the articular cartilage of the multiple joints that allow motion between each spinal vertebral body is removed to allow the vertebral bodies to grow together. This may be done when weakened vertebral muscles are unable to support a straight spine and scoliosis develops. Currently the techniques of spinal fusion involve the incorporation of metal rods and screws to hold the position of the vertebral bodies in correct alignment until they are fused together.

Some specific procedures:

Contracture release

a) Hip flexor and abductor contractures:

Ober Hip Release: Commonly this procedure is combined with the Yount release (see below)

Goals: Reduce hip flexion contracture (e.g. to allow child to stand erect without excessive lumbar lordosis)

Procedure: release of the fibrous tissue surrounding the muscles anterior to the hip joint. The incision is transverse

just below the ASIS and extends laterally about 7 centimeters laterally.
Immediate Post-Operative Program: patient positioning hip in extension (no pillow under knee)
Long term Post-Operative Program: hip extension exercises
Physical Therapy Goals: Gain and maintain as much hip extension ROM as possible. Gain and maintain hip extensor muscle strength. Incorporate ROM and strength gains into functional activities such as walking and standing. Teach patient and amily hip extension exercises including ROM and strengthening. It is likely that the patient has weak hip extensors that contributed to the development of the hip flexion contracture in the first place but once range of motion has been gained by surgery it may be possible to gain some improved muscle strength and the patient should be evaluated to see if this is an option. Also provide suggestions for improving the patient's gait and posture and preventing a recurrence by providing education about alternate positions for activities.
Other Hip Releases: Some surgeons have preferred to do extensive releases of the tissues around the hip joint including dividing muscles, tendons and hip capsule in an attempt to correct the entire contracture at one surgery. We believe that this is unwise because of the extensive tissue damage and the possibility of nerve and vessel damage due to excessive stretching. We recommend that contracture correction is done more gradually and incrementally.

b) Knee flexor release

Yount Release:

Goals: Reduce knee flexion contracture (e.g. to allow the child to fit properly into a brace) and reduce external rotation of the tibia on the femur.
Procedure: release of the ilio-tibial band just proximal to the knee. The incision is lateral. The ilio-tibial band is exposed and divided entirely down to its deep insertion on the femur.
Immediate Post-Operative Program: Usually a cast or splint; patient positioning (no pillow under knee)
Long term Post-Operative Program: e.g. Night splinting
Physical Therapy Goals: Obtain as much knee extension ROM as possible. Obtain increased strength in the quadriceps muscles to maintain or increase active knee extension if possible. Teach the patient and family ROM and strengthening exercises. Incorporate the increased ROM and strength into functional activities such as walking or standing. It is probable that the patient has weak quadriceps muscles that contributed to the development of the knee flexion contracture but it may be possible to gain strength once the contracture has been released and the patient should be evaluated to see if this is possible. Be sure to maintain a good balance between knee flexion and extension and active muscle control of both motions as possible. The patient should be encouraged to walk using the newly prescribed brace and the brace should be assessed for proper fit and function.

Knee Flexor Hamstrings release:

Goals: Reduce knee flexion contracture (e.g. to allow the child to stand properly in a KAFO.)
Procedure: release of the ileo-tibial band just proximal to the knee; release, or lengthening the Hamstring muscles. There are usually two incisions… one lateral and one medial, both are proximal to the knee joint and over the hamstring tendons. The knee joint capsule is not opened.
Immediate Post-Operative Program: Usually a cast or splint to maintain the knee extension gained at surgery. Sometimes the patient's leg is placed into skeletal traction after the release to provide gradual further straightening.
Long term Post-Operative Program: Night splinting may be used; continues active-assisted knee extension exercises, or passive extension exercises if inadequate knee extension power.
Physical Therapy Goals: Obtain increased knee extension ROM. Obtain increased quadriceps muscle strength. Maintain hamstring muscle strength. Incorporate increased knee extension ROM and quadriceps muscle strength into functional activities such as standing and walking. It is important to get as much active ROM as possible and hopefully increase quadriceps strength and control of knee extension. However, do not forget to ensure the hamstrings are working well since they will have been weakened by surgery in order to allow more knee extension ROM. Teach the patient to walk with the newly prescribed brace and evaluate the brace for fit and function. Teach the patient and family exercises and provide suggestions for positioning to prevent development of a new knee flexion contracture.

Serial Casting:

Goals: Reduce knee flexion contracture (e.g. to allow the child to fit properly into a brace)
Procedure: Application of a long-leg cast (toes to thigh). Approximately every seven to ten days the cast is either removed entirely and a new one applied under gentle extension stretching to gain about ten degrees of extension per cast change.
Alternatively, the original cast is not removed, but is partially cut transversely across the posterior aspect and the residual anterior cast cracked then extended to gain about ten degrees of extension and then overwrapped to hold the new position. Care is taken in both these techniques to avoid posterior subluxation of the tibia on the femur.

Immediate Post-Operative Program: Usually after the knee extension is achieved, a cast is used for several weeks to maintain the gain.

Long term Post-Operative Program: e.g. Night splinting may be necessary to maintain correction.

Physical Therapy Goals: During serial casting be sure the patient is able to maintain as much independent function as possible. This may mean teaching the patient to walk using a non-weight bearing gait with crutches or a walker. Or the patient may require a wheelchair temporarily. Maintain a general level of fitness while the patient's activities are limited. If the patient has active quadriceps function they can be taught isometric quadriceps exercises to do during the period of casting. Once the casting is complete the goal is to maintain the amount of knee extension gained. Teach the patient and family knee extension ROM exercises. Teach the family quadriceps strengthening exercises if possible. The patient may lack quadriceps function and that lead to the development of the knee flexion contracture; but, the patient should be evaluated for the possibility of gaining muscle strength once the ROM has been obtained. Be sure the patient has knee flexion through their full ROM as the knee can become stiff during the casting.

Tendo-Achilles Lengthening

Goals: To allow the ankle to dorsiflex so that that the foot can clear the floor on swing phase.

Procedure: Usually through a longitudinal incision the tendo-Achilles is exposed and cut in two through a "Z" incision and stitched together again in a lengthened position.

Immediate Post-Operative Program: Usually a cast or splint to maintain the ankle in a neutral position. The cast may extend above the knee to keep the gastrocnemius muscle at length.

Long term Post-Operative Program: Night splinting may be used; continues active-assisted ankle extension exercises.

Physical Therapy Goals: Obtain as much dorsiflexion ROM as possible. Increase strength of the tibialis anterior muscle if possible. Teach the patient and family ROM and strengthening exercises. Teach the patient to incorporate the post-operative ROM and strength gains into functional activities like walking and standing. Teach the patient and family preventive strategies so that the contracture does not recur. The patient may not be able to strengthen the tibialis anterior and that may have led to contracture development but the patient should be evaluated to see if strength gains are possible. If a brace is prescribed the patient should be taught to walk with the new brace and the brace should be evaluated for proper fit and function.

Other: **Plantar fascia release:**

Goals: Reduce a cavus contracture of the foot.

Procedure: Through a longitudinal plantar incision, the fascia is divided transversely

Immediate Post-Operative Program: Usually a cast or splint is worn for 6 to 8 weeks post-surgery to maintain the foot position gained at surgery.

Long term Post-Operative Program: Plantar stretching exercises are done daily. Night splinting may be used; metatarsal pads are worn in the daytime.

Physical Therapy Goals: Obtain and maintain a reduction of the cavus position of the foot. Teach the patient and family exercises to stretch the plantar fascia and mobilize other soft tissues as indicated. Teach the patient to incorporate the new foot position into functional activities such as walking and standing. Be sure the patient's footwear allows adequate space for the change in foot position. Teach the patient and family strategies for positioning to prevent redevelopment of the cavus position of the foot.

Deformity re-alignment:

Osteotomies such as **Proximal femoral** for Varus, valgus or rotation; **Supracondylarnfemoral** for extension or flexion; **Proximal tibial** extension; **Tibia or femur** for varus, valgus or rotation; **Acute leg shortening and lengthening**; **Humeral osteotomy** (for rotation).

Essentially these operations are similar to the treatment of fractures that require surgical stabilization of the fragments and time for bone healing. The factors that affect the time of stabilization are the age of the patient, the size of the bone that was cut and whether the bone will be needed to support weight bearing.

Physical Therapy Goals: A primary goal is independent mobility with crutches or a walker or wheelchair if the patient is not able to walk with equipment post-operatively. The patient with a lower extremity osteotomy will need to learn to walk with crutches or a walker to protect the osteotomy site during healing. The patient may need to progress from a non-weight bearing gait, to partial to full weight bearing with or without aides depending on whether they walked without assistance prior to surgery. The patient will need to maintain muscle strength during healing process and regain or increase strength and ROM of the affected joints once casting or other fixation has been removed and motion is allowed. The patient and family will need to be taught ROM and strengthening exercises and should be encouraged to help the patient remain as active as possible during healing. The patient should be taught to incorporate the new leg alignment while walking and standing. Be sure to check to see if the patient requires altered shoe wear, or bracing after realignment. For the humeral osteotomy the patient may need more assistance with ADLs depending on whether the osteotomy is on the dominant or non-dominant arm. Encourage the patient and family to keep the shoulder and elbow joints moving as possible while the osteotomy heals. The patient will be initially restricted in lifting objects with the operated arm probably for around 6 weeks. They may also wear a sling and or have an external fixation device placed on the humerus. Regaining strength and ROM in all upper extremity joints is critical so the patient can incorporate the new arm position into functional activities. Be sure to check that there are no post-operative changes in sensation or strength in the hand.

Fusions/Arthrodeses

Grice-Green +/- variants

Goals: To block the motion of the sub-talar joint either to reduce hindfoot valgus or to free up the peroneal and/or the posterior tibialis muscle so that they can moved to more useful function. The operation is used in children because it does not affect the growth of the foot bones.

Procedure: An incision is made in the lateral side of the foot over the subtalar joint and a bone graft is fixed between the talus and calcaneus. Grice described taking the graft from the proximal tibia but others have taken it from the distal tibia or oscalcis. Sometimes a metal pin in used to hold the bone graft in place.

Immediate Post-Operative Program: a long-leg cast is applied if the graft is taken from the proximal tibia, otherwise a short leg cast is used. The cast is removed 8 to 10 weeks later when x-rays show good bony union across the joint. Gradual weight bearing is encouraged, protected by crutch use.

Active (if possible) or passive (as necessary) exercises are encouraged to maintain or regain motion in the knee and ankle joints.

Long term Post-Operative Program: nothing special

Physical Therapy Goals: The patient should be taught to walk independently with either crutches or a walker. The patient may initially be required to be Non Weight Bearing but should be progressed to Partial Weight Bearing as soon as possible as this assists with bone healing. Be sure the cast has been shaped to allow for good foot alignment on the ground. An old shoe can be split and tied over the cast to protect the cast while walking if cast boots are not available. Once the cast is removed the patient and family are encouraged to regain strength and ROM of the joints affected. If the patient is in a short leg cast be sure the patient incorporates normal hip and knee motion into walking during the Partial Weight Bearing period. Once the cast has been removed the goal is to regain active or passive ankle ROM and strength and incorporate the new foot position into gait. Be sure the patient's shoes or braces are altered to accommodate the new foot alignment.

Triple Arthrodesis

Goals: To block the motion of the sub-talar joint and the talo-navicular and calceo-cuboid joints. This may be done to reduce pain in the hind foot joints, or for deformity (hindfoot varus or valgus) or to free up the peroneal and/or the posterior tibialis muscle so that they can moved to more useful function. The operation is not used in children under about ten years of age because it affects the growth of the foot bones.

Procedure: An incision is made in the lateral side of the foot over the subtalar joint and the joint cartilage between the talus, calcaneus, navicular, and cuboid bones is removed. Bone graft is not generally added. The joints are usually fixed in place with metal staples, screws or pins.

Immediate Post-Operative Program: a long-leg cast is applied. The cast is removed 8 to 10 weeks later when x-rays show good bony union across the joints. Gradual weight bearing is encouraged, protected by crutch use.

Active (if possible) or passive (as necessary) exercises are encouraged to maintain or regain motion in the knee and ankle joints.

Long term Post-Operative Program: nothing special

Physical Therapy Goals: The patient should be taught to walk independently with crutches or a walker. The patient should be progressed from Non Weight Bearing to Partial Weight Bearing as quickly as possible because Partial Weight Bearing promotes bone healing. It is also a more energy efficient gait. Be sure the cast is shaped to permit walking on the ground. An old shoe can be split and tied over the cast to protect it during walking if cast boots are not available. Once the cast is removed the patient and family need to be taught strengthening and ROM exercises. Regaining knee flexion and extension and quadriceps and hamstring strength is important. The patient will also need to be taught to walk with the altered ankle motion. It is very important to regain dorsi and plantar flexion and strength of the ankle muscles. Remember the patient will no longer have ankle inversion or eversion. Footwear and braces should be altered to accept the changes in foot alignment.

Shoulder Fusion or Arthrodesis:

Goals: Done in a patient whose deltoid is paralyzed and cannot actively abduct their arm and yet has active muscular control of the scapular muscles, the joint between the proximal humerus and the scapula is fused so that the humerus can be controlled by the scapular muscles.

Procedure: a) in children from about age 8 until skeletal maturity: the shoulder joint is exposed through a lateral incision and the articular cartilage is removed taking care not to injure the growth plate of the proximal humerus. The scapular-humeral joint is held in the appropriate position by two or more metal pins.

b) After skeletal maturity: the exposure is more extensive and the fused joints are stabilized with a heavy metal plate and screws.

Immediate Post-Operative Program: In children, a spica cast from finger tips to the waist is applied at the operation. The cast is removed after 6 to 10 weeks (depending on age) after x-rays show sufficient healing. The metal pins are removed at a second operation.

In adults, a cast may, or may not be used and exercises started to train the use of Active shoulder abduction

Long term Post-Operative Program: nothing special

Physical Therapy Goals: While the patient is casted provide suggestions for positioning to prevent neck pain and irritation from the weight of the cast. Encourage breathing exercises and good sitting posture with the cast supported as needed. The shoulder elevators and scapular abductors will need to be strengthened and overhead arm motion regained once the cast is removed. Since the shoulder will be fused scapular motion will cause the arm to elevate. It is important to get the serratus anterior, the lower, middle and upper trapezius and levator scapulae functioning along with the rhomboids. The patient will need to be carefully assessed to determine which of these muscles are working since the deltoid is paralyzed. A number of isometric exercises may need to be taught to strengthen a combination of these muscles. Then the emphasis is should be on functional activities such as reaching with the arm and hand.

Other

Epiphysiodeses:

Goals: To achieve equal leg lengths by the time skeletal maturity has been reached.

Procedure: The operation is done on the normal, longer leg. Through small medial and lateral incisions over the growth plate regions of the distal femur or proximal tibia (or both), the growth plate is exposed and obliterated by curetting or drilling.

Immediate Post-Operative Program: A cast or splint is used for 3 to 6 weeks. Weight bearing is encouraged as tolerated. The patient is encouraged to do exercises to prevent a knee contracture.

Long term Post-Operative Program: nothing special

Physical Therapy Goals: Teach patient a Partial Weight Bearing gait using crutches or a walker. Progress patient to Full Weight Bearing, without equipment, as possible in consultation with the surgeon over the course of healing. Gain and maintain normal knee flexion and extension and normal quadriceps and hamstring strength. If the patient is splinted it may be possible to remove the splint several times a day to work on active ROM and strengthening exercises for the knee. If the patient is casted for 6 weeks performing in cast exercises such as left lifts while sitting or active hip flexion/extension while standing will help maintain some leg strength until the cast is removed and knee flexion/extension exercises can be started. If available, ice can be used to help with post-operative swelling and discomfort.

"Guided growth"

Goals: To correct angular deformities of the bones, by slowing the growth of the growth plate (medial for valgus or lateral for varus deformity).

Procedure: The operation is done on the normal, longer leg through a small incision over the growth plate regions of the distal femur or proximal tibia (or both), the growth plate is exposed and a small metal plate is screwed proximal and distal to the growth plate.

Immediate Post-Operative Program: A cast or splint is not needed. Weight bearing is encouraged as tolerated. The patient is encouraged to do active exercises to prevent a knee contracture.

Long term Post-Operative Program: The angulation of the bones is monitored and when the desired correction has been achieved, the metal plate and screws are removed.

Physical Therapy Goals: Obtain and maintain normal use of the operated leg while walking. The patient may need to progress from Partial Weight Bearing with crutches or a walker to Full Weight Bearing without equipment. Obtain and maintain normal ROM and strength of the operated leg. The patient and family should be taught active knee flexion and extension with an emphasis on extension. Strengthening exercises should be provided for the quadriceps and hamstrings. If available, ice can be used to help with post-operative swelling and discomfort.

Skeletal traction after soft tissue release:

Goals: In patients who have not had medical care their joint contractures are too severe to fully correct at the time of surgical releases. The nerves and blood vessels have shortened and acute stretching would damage them.

Procedure: At the end of the surgical releases of the contractures, metal pins are inserted through the skin and across the ends of the femur and tibia. Weights are attached with ropes via pulley so that gradual traction can be applied over days and weeks so that the nerves and blood vessels can be stretched safely.

Immediate Post-Operative Program: When adequate straightening of the leg has been achieved, the pins are removed and a long-leg cast is applied for 3 to 6 weeks.

When the cast is removed exercises are started to regain ROM. These will usually be passive ROM exercises since the patient is unlikely to have adequate, if any, muscular activity.

Long term Post-Operative Program: An appropriate orthosis will need to be fabricated. While the patient waits for the finished brace, a splint will be used to maintain the range of extension gained by the traction.

Physical Therapy Goals: Gain normal knee ROM and teach patient and family to do passive ROM exercises. Caution should be used when performing passive ROM exercises as these patients often have some osteopenia due to lack of ability to weight bear fully on the paralyzed leg and also due to lack of normal muscle function in the leg. Gait training with crutches or a walker should occur. The patient can walk with the splint while waiting for the orthosis. Be sure the orthosis fits correctly and that the patient is able to walk well using the orthosis. Teach patient and family about appropriate exercises and positioning to prevent recurrence of the contracture.

Gradual Limb lengthening:

Goals: To increase the length of the short limb.

Procedure: After careful planning, metal pins and screws are placed through the skin across the bones and attached to metal rings. These metal rings are joined by threaded screw devices that will lengthen the distance between the rings when turned. The bone to be lengthened is then divided.

Immediate Post-Operative Program: About a week after surgery (to allow the cut ends of the bone to form a fibrous union) the lengthening begins gradually. The lengthening proceeds at about a millimeter per day until the desired length has been achieved over 2 to 4 months.

This lengthening period is the most critical for physical therapy. As the lengthening proceeds, the patient may develop a gradual uncorrectable knee flexion contracture, or posterior subluxation of the knee. They may also develop a fixed ankle equinus. Exercises must be done to maintain full knee extension and ankle dorsiflexion throughout the lengthening process.

If possible, the patient should be encouraged to walk with a support aid.

Long term Post-Operative Program: Exercises must be done to maintain full knee extension and ankle dorsiflexion

Physical Therapy Goals: Teach the patient and family exercises to prevent contracture development and to maintain lower extremity strength and ROM during the process of leg lengthening. Teach the patient to walk with Partial Weight Bearing or Full Weight Bearing with or without equipment as tolerated, as specified by the surgeon. The patient may need gradual adjustment to a shoe lift as the leg of the leg increases. They should walk with the foot flat on the ground if possible. Active ROM should be emphasized but if the patient is unable to manage active then active assisted or passive exercises should be taught. Maintaining knee flexion and extension and ankle dorsiflexion is critical. Initially the patient and family may be overwhelmed by the fixation device and the wound care required but it is very important to provide support and encouragement to keep the joints in the leg moving while the lengthening occurs. It is also important to monitor the leg and foot for changes in sensation or loss of strength suggesting nerve injury. If any change of this sort occurs the patient should be sent for an immediate consultation with the surgeon. Maintaining muscle strength in all the leg muscles is important and this includes the hip extensors and abductors.

Tendon Transfers such as **Anterior Tibialis Laterally** (for Supination); **Peroneus to Heel** (for Calcaneus); **Jones transfer** (Toe extensor to metatarsal); **Tibialis Anterior to center of foot** (for Dorsal bunion); **Mustard** (Iliopsoas to greater trochanter).

Goals: using the force of an adjacent, expendable muscle by moving its tendon to a different attachment point to gain a lost function or to prevent deformity of a growing bone due to unbalanced muscle forces.

Procedure: The different procedures are too varied to give a single simple description. The insertion of the muscle being transferred is detached from the bone. The tendon and muscle are dissected proximally, avoiding nerve and blood vessel damage, to allow them to be repositioned in straight line to the new bony reattachment area.

Immediate Post-Operative Program: aa plaster cast or splint is applied, usually for 3 to 4 weeks. Unrestricted use is allowed after about eight weeks

Long term Post-Operative Program: In patients with polio, the majority of tendon transfers are done in the lower extremity. The synergy, or "phase" of the transferred muscle is of more relevance than in most transfers done in the hand for peripheral nerve or spinal cord injuries. A patient following an "out of phase "transfer such as Posterior tibialis forward; or a Peroneal muscle forward or a transfer of the External oblique muscle to the greater trochanter are not as likely to automatically incorporate the new function as with transfers done in the hand where the patient can watch the new function perform. These patients are likely to require more specific training.

Physical Therapy Goals: If possible, assist the patient to gain active use of the transferred muscle in its new role. It is very critical for the therapist to know how strong the muscle was before it was transferred and what the surgeon hopes the patient gains post-operatively. Sometimes transfers are done to remove a deforming force and active function is not necessarily expected. For training, the therapist should see if the patient can initiate an active contraction in the muscle by using an in-phase function. For example, if the posterior tibialis has been moved forward to assist in dorsiflexing the foot it may be possible to get it to fire with foot inversion. It is also helpful to get the same muscle working at the same function on the non-operated side if the patient has a second functioning posterior tibialis. The therapist can resist inversion on the non-operated side and palpate for contraction while the patient tries for active inversion on the operated side. If the patient is able to activate the transferred posterior tibialis the therapist should then begin active assisted dorsiflexion with inversion. If the patient is able to accomplish this motion, then the therapist tries for active dorsiflexion with a neutral foot position (neither inversion or eversion). Then the patient trains at walking hopefully with active dorsiflexion sufficient to provide adequate foot clearance for safe ambulation. The principal is the same with the peroneal forward – try to stimulate the transferred muscle to work by asking the patient for eversion. For the tibialis anterior transfer try to initiate an active contracture by using inversion. It is helpful if the patient has an active muscle on the other leg so that he/she can feel the muscle working and understand more clearly how to "find" the transferred muscle. For the tibialis anterior that has been transferred posteriorly the patient needs to incorporate this muscle into plantar flexion during gait. With the external oblique transfer, have the patient attempt activation with trunk flexion in neutral. This should allow the patient to feel both external oblique muscles working and get activation of the transferred muscle.

Role of PT in Bracing e.g. Spines

Patients with spine deformities can be taught strengthening and flexibility exercises depending on the extent of their paralysis. Bracing can often be very difficult for patients with polio to tolerate and frequently not a success as far as preventing progression of scoliosis. If the patient has sufficient trunk strength to perform "in and out of brace" exercises then they should be taught to do so. For patients who are being braced attention should be paid to breathing exercises and to the potential for significant challenges to breathing while wearing a brace. Some patients with severe paralysis may benefit from extensive seating support. Providing a well designed seating system with appropriate lateral supports and teaching the patient and family how to use it may allow the patient increased function due to adequate postural support. Maintaining spinal flexibility may decrease pain and patients can be taught to perform self -traction by hanging from an overhead bar and letting the entire spine stretch out. This can be done from a wheelchair or from standing if the patient has sufficient arm and hand strength to suspend his/her self. If the patient has a spine fusion post-operative emphasis on breathing and coughing and transfers is important. Teaching the patient to "log roll" and to work with the newly acquired loss of spinal mobility during transfers and other ADLs will help make recovery and return to prior level of function smoother.

Orthotic Management for Individuals Affected by Poliomyelitis:

Introduction

Individuals affected by poliomyelitis may present with complex biomechanical problems that require the breadth and scope of a multidisciplinary team to fully assess and plan treatment. Once the team has established that orthotic intervention is appropriate, the orthotist should work toward an orthotic treatment plan with careful consideration of the unique presentation of the individual.

The orthotist should complete a comprehensive assessment that includes patient history and physical examination. Subjective history should include a detailed orthotic history if present. The physical assessment must include range of motion, muscle strength testing and any special tests needed to assess for stability of affected joints (1)The orthotist should perform dynamic assessment of gait and relevant functional tests to ensure that the assessment captures not only deficiencies identified in manual testing, but also any compensatory mechanisms that may have developed.

In gait, abnormal positioning and a longer stance phase on the stronger limb may be observed.(1) Some common biomechanical deficits reported in the orthotic users who have been affected by poliomyelitis include: inadequate dorsiflexion during swing, dorsiflexion collapse in stance, genu recurvatum, genuvalgum and frontal plane instability at the ankle.(2) While some deficits are the direct result of muscle imbalance they may also be rooted in the compensatory mechanisms users deploy to achieve stability. Compensatory gait patterns are often unique to each patient and can include but are not limited to:

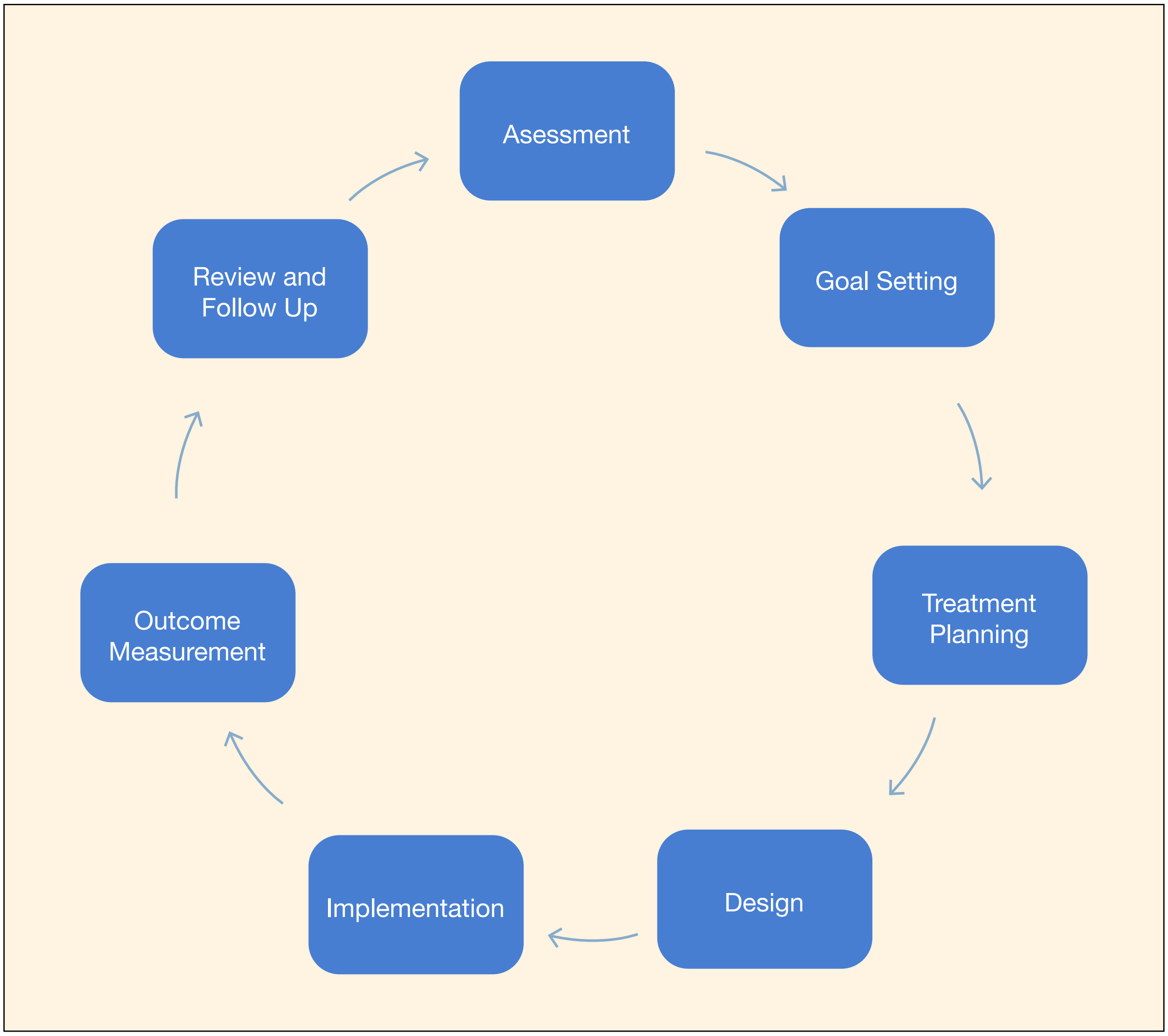


Figure 1: The cycle of orthotic treatment

- hand thrust gait - using the hand to force the knee into extension for stability
- lateral trunk/hip lean - to maintain stability caused by weak hip muscles
- External rotation of the hip to prevent the knee from flexing

Compensation strategies can be harmful in the long term and difficult to maintain over time.(3) Even before excessive or painful motion is identified mild to moderate gait deviations should be addressed in orthotic design to prevent more significant deformities and deviations from evolving. Gait should be assessed and documented to monitor the impact of orthotic intervention.

Development of the treatment plan should include both user and clinical goals. User goals will be unique to each individual and are of importance to ensure acceptance of the device, and in establishing treatment effect. The clinician should aim to include an objective measure of the treatment effect which allows for the monitoring of the condition over time.

Self-reporting user satisfaction tools or activity specific tools such as the Patient Specific Functional Scale4 may be of benefit to monitoring the goal attainment of users. Performance measure such as the 2-Minute Walk Test5 may be included6 in the initial assessment, at fitting and at follow up to monitor treatment effect. The Shirly Ryan Ability Lab – Rehabilitation Measures Database maybe a useful starting place to search for details and other relevant tools (https://www.sralab.org/rehabilitation-measures). Additional resources for implementing these and other outcome measures are available in the American Academy of Orthotists & Prosthetists in their "How to" Video Series (https://www.oandp.org/page/HowToVideos).7

For clinical goal setting the orthoptist must consider all three planes of motion, set goals for each affected joint and consider the three interfaces of orthotic intervention:

- Orthosis - Limb
- Orthosis - Footwear
- Footwear - Ground

The Orthotist or Associate Orthotist should plan treatment and communicate the plan to the user/family and other caregivers. This may include not only the orthosis but also other elements required to ensure that orthotic intervention can be optimized, such as the need for therapy, footwear modifications or other gait aids. The aim of orthotic design is to optimize function while ensuring the device is as light weight as is feasible (1). There is no singular design that can be applied to every user on the basis of diagnosis alone. The Orthotist or Associate Orthotist must synthesis a range of factors to create an individualized orthotic treatment plan to meet user and clinical goals. Clinicians should continually monitor and objectively measure outcomes to ensure the treatment plan is optimized.

Orthotic intervention can be used to address these risks and adverse outcomes individually or in combination. It is recommended that the Orthotist or Associate Orthotist define the desired orthotic goals and provide a functional description of the device in their clinical documentation and treatment planning.

Common clinical goals in individuals affected by poliomyelitis may include but are not limited to:

- Compensation for leg length discrepancy
- Reduce pain
- Distribute pressure
- Improve the base of support
- Maintain or increase range of motion
- Prevent progression of deformity
- Improve stability
- Reduce energy consumption

Common functional descriptions include these types of motion control:

- Free motion
- Assisted motion
- Resist motion
- Limit motion

Orthotic goals and functional descriptions should be used in developing the design of the orthoses and should be reviewed at follow up to monitor treatment affect.

It should be noted that when movement is restricted at one joint, the forces generated are transmitted to the next more proximal joint. For example if ankle/ foot motion is blocked the knee movement can be affected. This requires careful attention to position not just the ankle/foot but to optimize hip and knee function as well. In designing the orthosis clinicians must consider the alignment of the anatomical joint, the impact on proximal joints and the effect on alignment of all three interfaces mentioned earlier.

Device Considerations by Body Part

The following section will a provide summary of some of the key elements of orthotic treatment that are common among orthotic users who have been affected by poliomyelitis.

Upper Extremity

It has been noted by the International Society for Prosthetics and Orthotics (ISPO) in its consensus conference on poliomyelitis that for individuals affected by poliomyelitis, upper extremity orthotic treatment is not common. Orthotic devices for the upper extremity may be useful to improve function, or to prevent contracture/deformity if warranted. However, acceptance of upper extremity orthoses has been reported to be low, poor societal acceptance and limited functional benefit are among the reasons cited. A team approach and careful consultation with the user are needed to ensure the orthotic intervention can be successful.5

Spinal:

As is true for any orthotic spinal intervention, a team approach is required for individuals seeking treatment for the effects of poliomyelitis in the spine.

As a general rule, there is little role for bracing in the treatment of children with scoliosis due to poliomyelitis. Bracing a lumbar curve often makes walking impossible. Bracing a thoracic curve when the child has no muscles to withdraw from the pressures of an orthosis may lead restriction of respiration and to skin sores.

Incidence of scoliosis in poliomyelitis

The estimates of the incidence of scoliosis following poliomyelitis are often imprecise since they are based on physical examination rather than surveys by x-ray. In the Tajikistan poliomyelitis outbreak of 2010, of the 360 people personally (HW) evaluated by physical examination there were 39 who had scoliosis (11%). All but two were under 10 years of age at the time they contracted poliomyelitis.

Types of scoliosis

Scoliosis in poliomyelitis is generally seen in two groups of children:

1. The first are young children who suffer extensive paralysis of the trunk muscles and develop scoliosis very early, commonly within two or three years of the paralytic episode. The scoliosis in these children tends to be in the thoracic spine and the respiratory impairment often ensues. In regions with limited medical resources these children commonly die in early childhood.
2. The second are children in whom scoliosis develops gradually in later childhood. The scoliosis is usually in the lumbar region and the spinal curve may compromise the ability to walk or sit.

Problems of managing children with Scoliosis due to poliomyelitis

The management of scoliosis in poliomyelitis is very different from that of idiopathic scoliosis.

- The alignment and mobility of the spine can influence the ability to walk.
- Loss of lumbar lordosis following spine surgery or wearing an orthosis can be a major impairment to walking and sitting, if the hip extensors are weak since there will be no way for the child to lean back sufficiently to get the mass of the trunk posterior to the hip joints.
- A supple lumbar spine may be necessary not only for forward movement but also lateral "balance". This may be insignificant in a crutch-free and brace-free child, but it may be catastrophic in a marginal household walker. Limiting the lumbar spine may decrease (or totally prevent) the patient's ability to walk. Parents not warned of this potential difficulty will be justifiably upset if their child stops walking after a fitting with a lumbar orthosis.
- A severe lumbar curve can be a major difficulty in walking due to the resulting apparent leg length inequality. Additionally, if a child's curve is very supple, he may need to expend an extra effort to stretch out the spine before the push on the crutch straightens the spine sufficiently to allow clearance during swing phase. (see note below concerning the use of a LSO or TLSO corset made of circumference-adjustable fabric LSO or TLSO.)
- Children with paralytic scoliosis often use their curve, particularly the kyphotic and lordotic elements to balance their trunks. The great majority of children in non-Western countries sit on the floor. Following straightening the spine orthotically they are inclined to fall over like a spent top if they sit on the floor. Sitting in a chair corrects the problem but that solution may not be popular in a culture where socialization takes place at carpet level
- Referral of children between eight years of age and puberty for surgery:
- The spines of children under 14 years from this second group tend to be much more flexible than those seen in idiopathic scoliosis. Thereafter, the curves tend to become rigid quickly. Consequently, an increasing curve seen on upright x-rays, which would ordinarily signal the need for surgery in a child with idiopathic scoliosis, can often be ignored temporarily in younger children with poliomyelitis. The indication for surgery is not "progression alone", but stiffening of a progressing curve noted on bending radiographs.
- Some sitters and marginal ambulators with a flexible, collapsing spinal deformity may benefit from a well-fitted, circumference-adjustable fabric LSO or TLSO.(ref 8) Adjustability of the circumference of the corset is important because pulmonary function is optimized at some mid-range abdominal constraint level. The swing-to crutch ambulators will find that the corset moderately reduces the energy required for ambulation. The abdominal constraint decreases the amount of spinal collapse each time as ambulation transitions from shoulder weight bearing to pedal weight bearing.

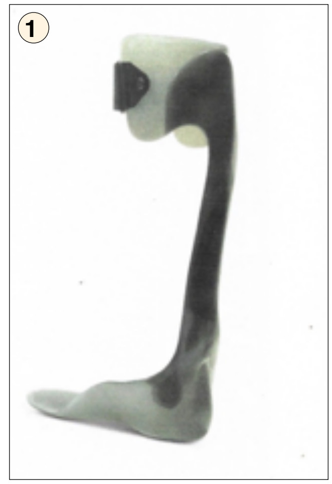


Figure 1: Energy Storage adn Return AFO. Photo courtesy of Boundless Biomechanical Bracing, reprinted with permission.

Figure 2: AFO with custom molded ankle strap made of foam and flexible plastic. Photo Courtesy of Boundless Biomechanical Bracing, reprinted with permission.

Lower Limb

For the lower extremity, orthotic intervention is considered a preferred method of treatment in most cases, except: (5)

- where surgery is needed to facilitate orthotic intervention
- the patient is non-compliant
- the patient is unwilling to use an orthoses
- where surgery can reduce or minimize the need for orthoses or footwear
- where orthotic intervention is impossible or ineffective5

Orthotic treatment is generally recommended in cases where walking ability is diminished, the patient is having falls or if there is pain from overuse or abnormal biomechanics.1 For some users the goal may be to prevent adverse outcomes associated with pain, muscle imbalance or joint instability such as contracture or deformity.

Ankle/Foot

When orthotic intervention is indicated at the ankle/foot, instability is typically treated by correcting towards a stable position. For individuals with fixed deformities the clinician should accommodate the deformity to prevent progression and provide stability.5 A variety of Ankle Foot Orthoses (AFO) may be appropriate for individuals affected by poliomyelitis. It is important that the Orthotist or Associate Orthotist consider the goals and desired function of the orthoses when selecting the design that best meets those criteria.

Flexible AFOs (or posterior leaf spring) are light weight and provide effective swing phase control for individuals who present with drop foot. It may also help control the transition from heel strike to foot flat thus reducing foot slap.(1)The user must present with stance phase stability, as this design offers little support or transmission of ground reaction force to the proximal joints in weight bearing.

Semi Flexible or Semi Rigid AFOs (or Energy Storage and Return-ESR) looks similar to the flexible AFO (see Figs. 1 & 2) however the posterior strut is designed to increase resistance to bending. This is typically achieved by reinforcing or modifying the shape of the strut using additional layers of plastic and/or shaping the strut to increase its curvature. This design allows for increased stability in stance and improved propulsive leverage at push off. The strut allows some degree of movement in weight bearing while resisting plantarflexion in swing phase. This design may be effective in restraining some degree of dorsiflexion collapse in stance. This low profile design is highly adaptable and can be easily tuned to the specific needs of individual patients.

A Rigid AFO (or Solid Ankle) provides stability in stance by blocking plantarflexion, dorsiflexion, and preventing motion in the frontal and transverse plane. It is indicated when a high degree of instability exists, or motion is painful. These orthoses tend to be bulkier and harder to fit into shoes than the AFO's described earlier. A rigid AFO may require a rocker sole to be added as this AFO does not allow forward progression of the tibia in stance phase. (1). Usually the rocker sole will be added to the footwear (see Fig. 5). The rocker profile may be added to the AFO if the device is too be worn at times without footwear. Attaching the rocker sole to the AFO can be less effective if the AFO is mainly worn inside a shoe, as forward progression can be dampened by the orthoses-shoe interface. For individuals with weak knee extensors the rocker sole can result in knee instability so should be used with caution and careful adjustment. (1).

Articulated AFO (or Hinged or Single Axis) (see Fig 3) allows the selection of range of motion. Joints can be chosen to improve frontal plane stability or to allow a desired range of motion in the sagittal plane. Typically plantarflexion can be controlled well, while dorsiflexion control may be more difficult. (1).A plantar flexion stop with free dorsiflexion movement may be desirable for individuals who have difficulty rising from a chair or where climbing stairs is an important activity.

Ground Reaction AFO (or Floor Reaction) prevent anterior progression of the tibia and can therefore be effective in stabilizing the knee during stance. This design may be rigid or articulated and can be of benefit to those with balance issues or to minimize energy costs. (1). (see further discussion of Ground Reaction AFO below).

A conventional AFO (or Double Metal Upright) is an older design, typically indicated where the patient has significant edema or has a long history of using this type of orthosis. (1). It does not possess the same ability to distribute pressure as a plastic AFO. This design is typically heavier and less transferable between footwear. These factors generally limit the selection of this design to those who have been long time wearers of conventional AFOs, or situations where plastic AFOs are not an option.

Knee

When knee buckling, hyperextension or frontal plane instability cannot be controlled by an AFO, a Knee Ankle Foot Orthosis (KAFO) may be necessary to achieve stability or correct alignment. When muscle weakness extends to the quadriceps and results in knee buckling, a locked knee KAFO may be required (2).

A range of knee joints both locked and unlocked (free motion) exist for use in orthotic designs to control knee motion and stability. Regardless of the locking mechanism when aligning knee joints it is important to remember that genu recurvatum is a common presentation for individuals affected by poliomyelitis. Excessive recurvatum can result in pain, but up to 10 degrees of hyperextension may be necessary to achieve stability. (3) Drop lock (or ring lock) knee joints are strong, cheap and provide safe reliable locking. They typically require two hands to operate and may not be ideal for individuals who require bilateral KAFOs, or have balance issues or problems with upper limb dexterity. (1)

However they are commonly used for individuals who are at risk of knee buckling (2) and are consistently stable regardless of terrain which cannot be said of unlocked (free) joints. A variant of this type of lock is the cable release drop lock.

In this variant a cable is attached to each side of the lock which allows them to be lifted simultaneously. This offers the advantage of single hand operation. They are less bulky than bail locks but have the

disadvantage of being somewhat difficult to unlock if leg does not have full extension range of motion. In addition, the cable must be worn over clothing or grasped through trousers or skirt.

These joints are more expensive and can also require more maintenance than other joint types, making them less desirable for those with limited access to orthotic services.

Another locked knee joint option is a Bail (Lever or Swiss) lock, which uses a connecting rod behind the popliteal fossa to make unlocking easier. They can be unlocked by lifting the rod, or backing up to a chair and releasing the lock against it without any hand use. While this can be a great convenience, especially for an adult, in the rough and tumble of a child's life the bar can accidently be bumped leading to a fall plus the added childhood "accident" provoked by a mischievous playmate.

They can add a small amount of bulk and weight which may be undesirable for individuals with poliomyelitis who experience fatigue.

Posterior offset joints have been advocated for individuals who present with unilateral genu recurvatum. (1) It is of importance to ensure the user can maintain an extension moment at the knee, as this joint does not prevent knee flexion. Those with active hip extensors or who can generate an extension moment by other means may benefits from this type of joint. This unlocked knee joint allows for ease of sit to stand and may reduce gait deviation associated with a locked knee joint such as circumduction and hip hiking. Caution should be exercised on uneven ground or unpredictable terrain as these surfaces can change the line of action of theground reaction force which may result in instability.

To properly align a posterior offset joint one practical method for determining an appropriate angle has been described by Lovegreen et. al. These authors recommend using a weight bearing test to determine the appropriate angle. The test is performed by backing the user against a wall with their involved popliteal fossa against the wall. The authors recommend slowly adjusting the user so that his or her back get closer to the wall thereby reducing the knee hyperextension. Once the users feels as though the knee might buckle the clinician reverses the movement slightly until the user feels stable. Then the clinician allows 5 additional degrees of hyperextension, which should provide a practical starting point for aligning the joint.1 This process identifies the point where the patient feels stable. Then by allowing 5 additional degrees of extension the patient should be safe, while preventing pain and adverse effects of end range.

For valgus/varus deformity and/or instability of the knee, orthotic intervention in the form of a KAFO is considered to be an effective conservative approach to management.5 The clinician should carefully assess the tolerance to correction, and design the frontal plane control to distribute pressure and optimize the corrected position. The clinician will need to determine if the position can be achieved during casting and/or if other mechanisms such as carefully positioned control straps are needed. Frontal plane instability or deformity can be managed with a free motion (or unlocked knee joint). This type of joint allows sagittal plane motion and therefore should have a less detrimental effects on gait when compared with locked joints. The patient must be able to stabilize the knee in the sagittal plane to prevent flexion.

The use of Ground Reaction AFOs (GRAFO), for patients with knee instability due to poliomyelitis polio paralysis is controversial. Biomechanically, the orthosis provides knee extension stability by forcing the tibia posteriorly, which is accomplished by preventing ankle dorsiflexion. The tibial extension force is enhanced by replacing the proximal strap of a standard AFO by plastic. This requires a posterior entrance for the foot and ankle

Most orthotists have been taught that such an orthosis is not practical for polio patients because they cannot rely on the stability for the knee especially as the ground surface is often very irregular, particularly for regions where most polio patients are encountered. Others, especially Dr. Benjamen Joseph in India, have a treated number of satisfied patients in GRAFOs (especially with Lehneis modification i.e. high popliteal trim line and suprapatellar extension) which are lighter and cooler. As the decades have progressed many of the countries where polio was once rampant now have streets and buildings where the ground is level and not irregularly covered with stones. Some patients have chosen to use a KAFO while out-of-doors or places of crowds and converting to use a GRAFO while indoors so that they may conduct business indoors giving them more comfortable maneuverability.

Hip

At the hip joint, orthotic intervention is considered ineffective in managing abduction, flexionand rotational deformities; but may be effective in managing rotational weakness.5 However, it is important to consider that the increased weight of the orthosis and energy consumption resulting from the inclusion of a hip joint and pelvic band often result in poor tolerance3 and limited benefit to the user. If the younger child cannot balance the trunk over the legs, a pelvic band and hip hinges may be added to the long-leg brace initially. When both hip extensors are paralyzed, a hip lock can be added. As the child gains confidence over a few months, it has been our experience that the need for long-term use of a pelvic band has been virtually zero as the patient becomes used to KAFOs.

Other Considerations:

Leg length inequality (see section above for a full discussion)

It is common for leg length discrepancy to be present in individuals who are affected by poliomyelitis. The clinician should carefully assess the different lengths of anatomical segments and the functional impact of leg length discrepancy. Differences may be caused by reduced lower limb growth, contracture, deformity, alignment, joint instability and/or orthotic design. The orthotic design will need to take into consideration the thickness of materials, as well as the accommodation or correction of deformity such as a heel lift for an equinus foot, or correction of valgus/varus deformity. Locking or blocking the range of motion at a joint may result in a functional leg length discrepancy. Insufficient suspension may also allow the orthoses to slip or piston down during swing phase. This results in a functional lengthening and the potential for gait deviations normally associated with leg length discrepancy even if static measurement suggests the length is correct.

It may be necessary to allow the limb to be effectively shorter to facilitate clearance in swing.

Straps

Straps are important elements of any orthotic design. They can be used as a simple method of suspending the device onto the user, or as a complex element of biomechanical control within the orthotic design. As a result of the atrophy typically present in individuals affected by poliomyelitis, care is needed to position straps correctly and ensure they are properly padded Straps used to control instability should maximize surface area. They can be custom molded using foam, and leather or flexible plastic (see Fig. 4).

Attachment points should be carefully selected to ensure that control is established and maintained. For example, if frontal plane correction at the ankle is needed to control inversion instability, a custom molded strap that covers the dorsal and lateral aspect of the ankle should be attached to the internal lateral aspect of the orthosis posterior to the lateral malleolus with the strap connecting to the external medial aspect of the ankle section of the orthosis, thus pulling to encourage a corrected position.

At the knee, a 4-point knee strap can be used to help control knee flexion. The points of attachment should be as close as possible to the knee joint while limiting the direct force applied to the patella and not impeding function of the mechanical knee joints. The limiting of force application relies on careful modification of the cast to ensure the knee pad has been properly shaped and molded to avoid pressure directly on the patella.

Even when not used for higher force applications such as correction of deformity or supporting instability, suspension straps should be carefully planned to ensure the device is comfortable and reliable for its intended purpose.

In a KAFO, 2 straps are typically used on the thigh to distribute force and allow adjustability in the fit. The distal strap is usually parallel to the ground and should be place as close to the knee joint as possible without impeding the operation of the knee joint. The proximal strap is typically angled to prevent circumferential constriction around the proximal thigh and is positioned as proximal as feasible.

Increased strapping or anterior support may be needed if ischial weight bearing is desired to off load a painful limb, as simple strapping is usually insufficient to maintain the ischium in a supported position.

The AFO (or AFO section of a KAFO) typically has a proximal strap usually within 1cm of the proximal trim-line, or as close to the knee joint as mechanically feasible. For adults this strap is usually 5cm in width, smaller straps may be used for children or slighter adults. At the ankle, straps vary depending on footwear. If good suspension is offered by the shoe, some users will not require an additional strap. This generally requires an enclosed shoe with an adjustable closure such as running or other sport shoe. If the footwear choice of the patient provides limited suspension, the strap should be designed to maintain suspension and/or control.

A single strap, parallel to the ground on the distal tibia, can be effective to prevent forward movement of the tibia inside the orthosis. This type of strap has little impact on the vertical control of the device so may allow downward slippage of the orthosis (a.k.a. pistoning) during swing phase.

An angled strap (usually about 45 degrees to the ground) placed at the ankle joint is effective in controlling forward movement of the tibia inside the orthosis and suspending thedevice during swing.

For adults, this strap is normally about 2.5cm wide. Wider straps can bridge the ankle joint over the dorsum of the ankle, reducing the effectiveness of the strap and may cause pressure at the edges of the strap. For those with significant equinus deformity, the dorsum of the ankle presents with a broader surface allowing for the use of a wider strap to distribute forces without causing negative effects.

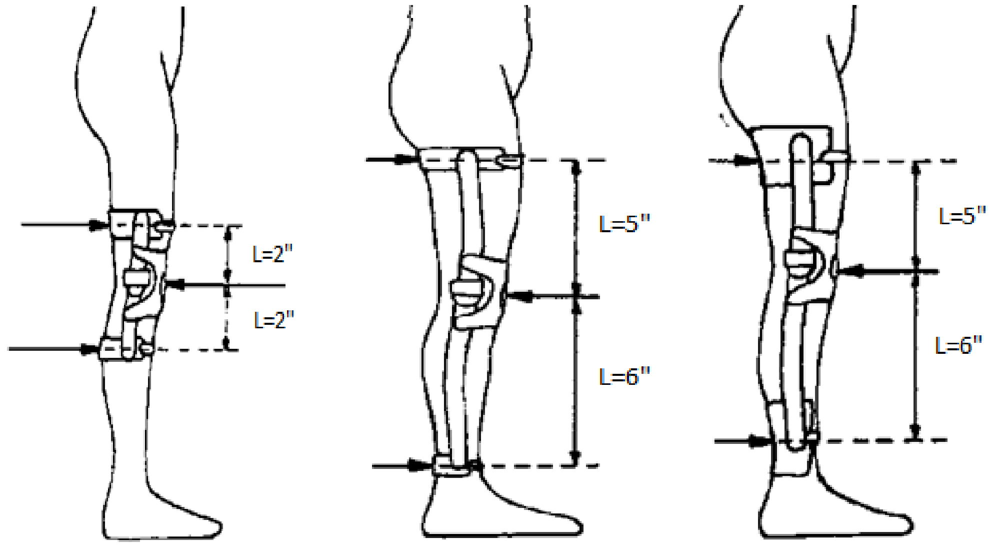
Sometimes it may be necessary to add a strap in the forefoot area to ensure good contact between the foot and the foot section of the orthoses

Figure 3: Articulated AFO with ankle strap at 45 degrees. Photo Courtesy of Boundless Biomechanical Bracing, reprinted with permission.

Figure 4: Footwear Modification Lateral Buttress to Improve Frontal Plane Stability. Photo Courtesy of Boundless Biomechanical Bracing, reprinted with permission.

Figure 5: Rocker Sole with shoe lift. Photo Courtesy of Boundless Biomechanical Bracing, reprinted with permission.

Reduction of pressure by using longer lever arms and increased areas of contact, when applying corrective forces to the knee joint.



A: Short lever arms
Small contact Area
Resulting high pressures

B: Long lever arms
Small contact area
Resulting lower pressures

C: Long lever arms
Large contact area.
Resulting lowest pressures

or to facilitate donning the device or footwear. This should be done with careful consideration for the purpose of the strap. Assessment of the foot position, careful casting/modification and fitting of the orthosis are crucial. Straps should not be used to mask a poorly fitting orthosis. For example, as various degrees of cavus and equinus can present in the foot of a person affected by poliomyelitis, the foot section can sometime have good contact in the rearfoot, while the forefoot is floating above the device. In this case placing a toe strap to force contact with the foot plate may result in the orthoses encouraging deformity, rather than supporting the foot and preventing progression of deformity.

Straps to control instability or prevent progression of deformity of the foot should be carefully padded and positioned using foam, leather or flexible plastic. A strap may be used only to assist donning, in which case it should be made of a thin narrow material such as Velcro or neoprene to allow for ease of shoe fit.

In settings where cost, weather, social norms or other factors influence use of footwear it is of importance that the orthosis is designed to ensure that the user can wear the device at the times and under the conditions that are important to them. For example, in cultural or religious contexts where footwear must be removed it may be necessary to add a sole to the orthosis, so it can be worn independent of footwear. In this case optimizing suspension free of footwear is necessary.

Footwear

Footwear should be seen as an integral part of orthotic design. Once the stability of the interface between the orthosis and footwear has been established it is important to consider the interface between the shoe and the ground. Stability can be influenced by base of support (Fig. 7), the height of the sole, heel height, and by use of a rocker sole (Fig. 6) to smoothen the transitions in stance phase. (1)

Fitting

It is important that a systematic approach to fitting orthoses is used. The orthotist should begin with bench alignment where the device is assessed with user's footwear, before it is donned by the user. This allows for a preliminary assessment of the alignment and stability of the Orthosis–Footwear and Footwear–Ground interfaces.

Bench alignment is followed by static alignment where the device is donned by the patient and then assessed for appropriateness of fit and alignment. Dedicating time and consideration to static alignment is often over-looked in orthotics but it can be an important tool to facilitate dynamic alignment and improve efficiency in reaching a desirable outcome.

Static alignment begins in non-weight bearing to assess the initial fit of the device. Contours, control and comfort should all be checked during this stage, and any changes needed to ensure the safe comfortable use of the orthosis should be made.

Static alignment continues with a weight bearing trial of the device. The user should stand wearing the orthosis equally weight bearing on both limbs. The fit and alignment of the orthosis should be checked systematically in all three planes. The user should be asked to lift the affected leg to monitor the quality of suspension. Any pistoning should be observed and appropriate action taken to improve suspension. Some pistoning may be unavoidable depending on the limb shape and volume, however the aim should be for 1cm or less of pistoning. Resolving pistoning may be a simple as tightening straps or modifying trim lines to improve contact. It may also be necessary to adjust the fit and contours to improve control before the user begins to walk.

Once the static alignment is satisfactory, and the device is comfortable dynamic alignment (where all three orthotic interfaces i.e. orthosis-limb, orthosis-footwear, and footwear-ground, are assessed) can begin. Gait should be observed in all three planes and the fit / function monitored with normal user activities. This stage may include task specific testing or outcome measures to ensure a complete analysis of the device fit and function has been achieved.

Follow up

At initial follow up (a period usually 1-3 months after the orthosis is delivered) the patient should be seen to assess the outcome of treatment following a period of acclimation to the device. The Orthotist or Associate Orthotist should check the fit and function of the orthosis, to ensure the orthotic treatment plan has been optimized. Gait should be reassessed after this period of acclimation; achievement of user and clinical goals should be re-assessed, and changes implemented if necessary.

Patients should be advised that the routine follow up is recommended to monitor the orthotic treatment plan and to assess the mechanical status of the device. The time for follow up will vary based on a range of factors (e.g. activity level, weight, working conditions, etc.). Most patients should be seen at least every 2 years.

For young children it may be necessary to review the orthosis every 3-6 months, or as signs of growth or change in function occur.

Maintenance

The patient should be instructed on the cleaning and care of their orthosis, as well as when routine maintenance should be performed by the orthotic provider.

- Cleaning pads, straps and plastic,
- Basic maintenance of mechanical joints.

Instructions should be specific to each patient and their unique treatment plan.

Biomechanical Principles of Orthotics:

Distribution of forces

Generally, poliomyelitis results in pronounced muscle atrophy and reduced soft tissues areas with pronounced bony prominences that have low tolerant to applied pressures.

Therefore orthoses for patients with polio paralysis it is important to use:

- Areas of contact as large as possible, with good surface matching of orthosis to body segment, and
- Lever arms as long as possible so the pressure is minimized.

Reduction of pressure by using longer lever arms and increased areas of contact, when applying corrective forces to the knee joint.

Straps are used to maintain contact between the orthosis and body segment, and apply corrective forces as part of the orthosis/body force system. To minimize pressure at the orthosis/body interface, the area of contact of each strap should be as large as practical.

Muscle imbalance in Polio and effect on gait

Effect of weak knee extensors on gait

The quadriceps muscles are the primary knee extensors.

They work:

-In loading response: To control knee flexion caused by the GRF
-In the first half of midstance: To extend the knee against the GRF
-In pre-swing: To control knee flexion caused by the GRF
-In Initial swing: To control knee flexion casued by momentum from hip flexion
-In terminal swing: To extend the knee ready for initial contact

If the quadriceps are weak, the patient will adapt their gait during stance phase to minimize the external flexion moment at the knee and so reduce the amount of work required by the quadriceps muscles.

They may do this by:

Hyperextension of the knee (Figure 1):

- This moves the knee posteriorly relative to the GRF
- The patient may utilize soleus to recline the tibia or the hamstrings/gluteals to incline the thigh
- They may also use their hand to push the thigh into an inclined position

Anterior Trunk Bending (Figure 2)

- This moves the center of gravity anteriorly and so moves the GRF anterior to the knee

Some patients may use a combination of these methods

The above adaptions also decrease the external flexion moment during pre-swing which in turn reduces the amount of flexion seen during initial swing. This often results in a decreased step length on the affected side.

Effect of weak knee flexors on gait

The hamstrings primarily work during terminal swing to control knee extension ready for initial contact. If the hamstrings are weak, some hyperextension of the knee may be seen during terminal swing and initial contact.

The hamstring tendons are also key to maintaining stability of the knee joint capsule during extension. If there is very low tone in the hamstrings, resistance to hyperextension will be decreased and genu recurvatum may develop.

Effect of weak hip extensors on gait

Gluteus maximus is the primary hip extensor muscles and is aided by the hamstrings.

They work:

-In loading response: To extend the hip against the external flexion moment from the GRF

-In terminal swing: To decelerate hip flexion ready for initial contact

If the hip extensors are weak, the patient will adapt their gait try to create an external extension moment at the hip during loading response and so minimize the amount of work required by the hip extensors. This is often achieved by a posterior lean of the trunk (Figure 3).

This moves the center of mass posteriorly so that the GRF falls behind the hip.

The patient may also reduce step length on the affected side as this will keep the GRF more vertical will reduce the normal hip flexion moment just after initial contact.

Effect of weak hip flexors on gait

Iliopsoas is the primary hip flexor muscle. It is aided by rectus femoris, adductor longus and several other smaller muscles

They work:

-In terminal stance: To control the hip extension caused by the GRF (only a very small amount of work is required as the ligaments of the hip joint also resist extension

- In Pre-swing: To flex the hip against the GRF and advance the limb
- In Initial Swing: To continue advancement of the limb

If the hip flexors are weak the patient will usually compensate by using the trunk and pelvic muscles to advance the limb during swing phase.

Are the goals set achievable and relevant?

- If not, redefine your goals and follow the cycle again.
- If your goals are achievable and relevant, does your prescription need to be changed to ensure they are met?

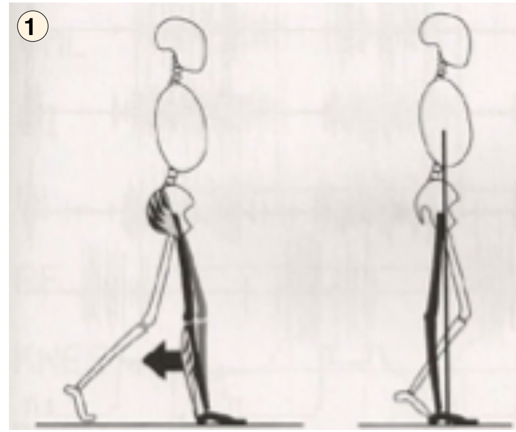


Figure 1: Hyperextension of the knee

Figure 2: Anterior Trunk Bending

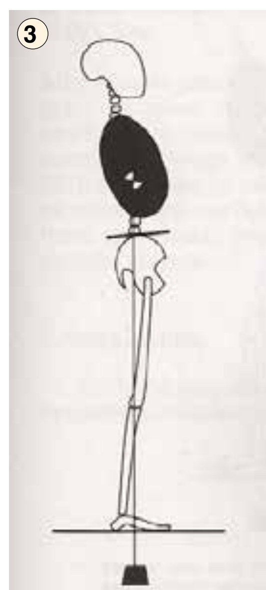


Figure 3: Posterior lean of the trunk

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Appendix:

A) ISPO: The International Society for Prosthetics and Orthotics

The International Society for Orthotics and Prosthetics was founded in Copenhagen, Denmark, in 1970. ISPO has flourished as a multi-disciplinary organization whose members are from the fields of orthotics, prosthetics, rehabilitation engineering and healthcare delivery services related to caring for those with disabilities. ISPO functions as an international, impartial, non-political organization. It provides for scientific exchange, promotes research and development in Prosthetics and Orthotics, guides and supports education and training and facilitates high standards of practice

ISPO has 2,500 members: 40% are Prosthetists and Orthotists, 25% are physicians and surgeons, 10% are therapists, 7% are engineers, 5% are shoemakers and 15% represent varied allied health professions.

ISPO works closely with a number of international organizations coordinating its activities with them, including the UN, the WHO, the International Labor Organization, and the International Committee of the Red Cross. Government aid programs cooperating with ISPO include GTZ in Germany and the United States Aid for International Development Fund. International organizations represented on the Board in an advisory capacity include Rehabilitation International, World Orthopedic Concern, Interbor, International Committee of the Red Cross, Handicapped International, and War Relief Fund.

ISPO is actively involved in research. Devices commonly available in the non-industrialized nations have been evaluated for their durability and practicality.

The most active area where ISPO has made a significant contribution has been in the educational field.

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Practical Surgery Book - 2,500 downloads