ORTHOLETTER

A NEWSLETTER ON ORTHOPAEDIC TECHNOLOGY IN DEVELOPING COUNTRIES

Number 7

In this issue:

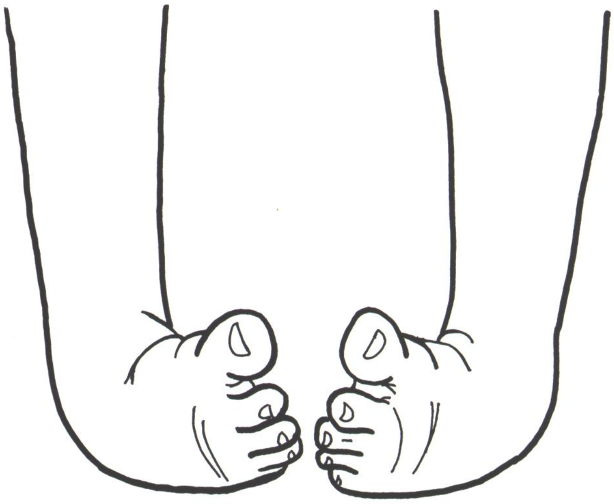
Linking orthotic services to CBR

Provision of orthoses in rural India

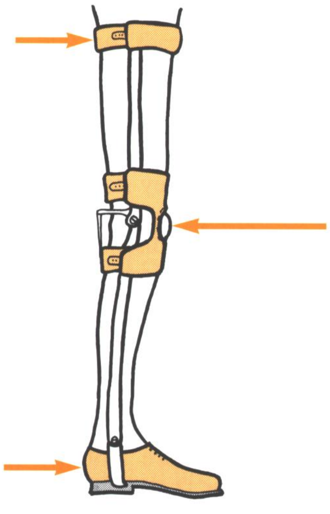
In 1992, an orthotics workshop was set up in the rural Raichur District of Karnataka State in India. Since formally trained technicians are reluctant to work in an area as remote as Raichur, the workshop must rely on workers who are locally trained. Apart from normal services given directly at the workshop, the staff also provide outreach services. In neighbouring villages, children are fitted with needed orthotic appliances, such as polio calipers and clubfoot orthoses. The work is done jointly with local CBR workers who later on can do the necessary follow-up. .... **page 2**

What is a clubfoot?

Clubfoot (*Congenital Talipes Equinovarus*) is a malformation of one or both feet, which, if not treated, may develop severe deformities. However, if given treatment at an early stage, preferably starting already during the first days after birth, the clubfoot may often be successfully corrected. Clubfoot treatment may include manipulation, casting, strapping and surgery, as well as the use of orthoses to maintain the position of a corrected foot. In many of its aspects, the work is delicate and it puts great responsibility on all the people involved, including the children's parents. .... **page 5**



Clubfoot (*Congenital Talipes Equinovarus*)



Three-point pressure system

Biomechanics in Prosthetics and Orthotics (4)

This part of *Biomechanics in Prosthetics and Orthotics* will deal with some issues that more closely relate to daily work in prosthetic and orthotic fitting. We will see how the *stability* of an object can be determined and what factors influence the stability, of an object as well as of the human body. We will also learn what is *pressure* and see the importance of using as great contact areas as possible in orthopaedic appliances. Finally we will see how forces are applied in orthoses in so-called *three-point pressure systems*. Concerning pressure, by the way; how is it possible that a 50-kg woman wearing spike heels in walking may exert a pressure that is much more than that of a 2-ton elephant? You will know after reading this part of *Biomechanics in Prosthetics and Orthotics*. ....**page 9**

Biomechanics in Prosthetics and Orthotics (4)

In previous parts of *Biomechanics in Prosthetics and Orthotics* we have learnt that two conditions must be met before equilibrium exists; 1) the sum of all the *forces* acting on the object must be equal to zero, and 2) the sum of all the *moments* about a point must be equal to zero. These two conditions may be noted:

$$\Sigma \mathbf{F} = 0$$
$$\Sigma \mathbf{M} = 0$$

In this part we will, among other things, see what factors determine the *stability* of an object, and how this knowledge can be applied to the study of the human body. We will also learn what is *pressure* and a *three-point pressure system*.

Stability

In order for an object to remain upright, a vertical line from its *centre of gravity*[1] must fall within the *base of support*. (The *base of support* of an object is the complete area under and between the object's supporting members, see Figure 1). If the line falls outside this area the object will fall. A book, for example (Figure 2), may be pushed far out over the edge of a table, but it will not fall off as long as its centre of gravity is supported (even though a large part of the mass is not). As soon as the centre of gravity passes over the edge of the table, however, the book is bound to topple off.

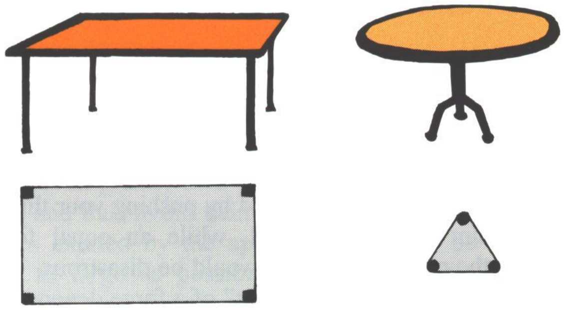


Figure 1. The base of support of an object is the complete area under and between the supporting members in contact with the ground.

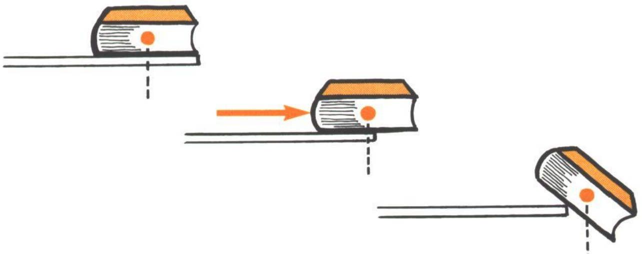


Figure 2. The book will only fall off when the centre of gravity is no longer supported.

Let us now study two identical objects placed in two different positions, lying and standing (Figure 3). Both objects are at rest, which means that, for both of them, the vertical line from the centre of gravity falls inside the object's base of support. We can see, however, that the line of the standing object falls closer to the border of the supporting area than that of the lying object, something which will influence the behaviour of the objects when they are pushed upon. Thus, if acted upon by an external force (Figure 4), the lying object (A) will return to its original position since the vertical line from its centre of gravity will remain within its base of support. If the same force is acting upon the standing object (B), however, the object will fall since its centre of gravity will no longer be supported; the vertical line from its centre of gravity will fall outside the base of support and equilibrium can no longer be maintained in standing position.

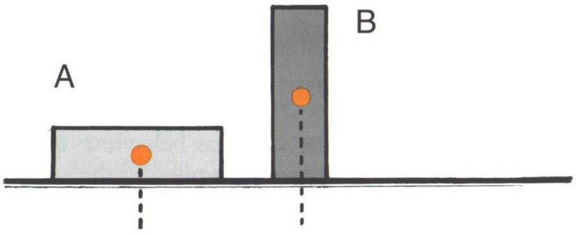


Figure 3. Depending on whether the object is lying (A) or standing (B), it will act differently when pushed upon.......

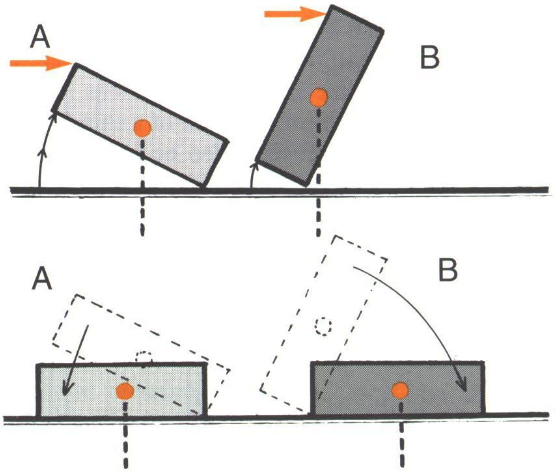


Figure 4. The lying object (A) tends to return to its starting position, while the standing object (B) falls. In B, the line of gravity falls outside the original supporting base and the centre of gravity drops to a lower point when compared to the starting position.

In biomechanics, and as just exemplified above, the **stability** of a rigid body is determined by studying the body's behaviour when it is acted upon by a suitable force. Thus, if the body tends to return to its starting position after being acted upon by the force, its equilibrium is said to be *stable* (object A). If, on the other hand, the object tends to increase its displacement, as a result of the applied force having caused the line of gravity to fall outside the base of support, the body is said to be in *unstable* equilibrium (object B).

Thus, in general terms, the stability of a rigid body depends on the relationship of the line of gravity to the base of support. Specific factors that influence stability are the *area* of the base of support, the *height* of the centre of gravity above the base and the *weight* of the body. The greater the base of support, the lower the centre of gravity and the greater the weight, the greater the stability of the object will be (Figure 5 - 7).

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[1] *Centre of gravity*, see first part of this series.

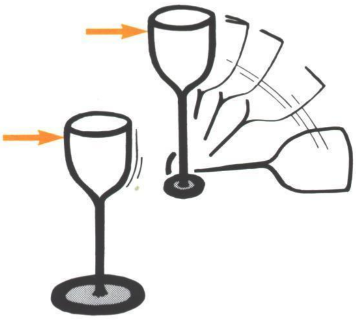

Figure 5. An object with a large base of support is more stable than an object with a small base of support.

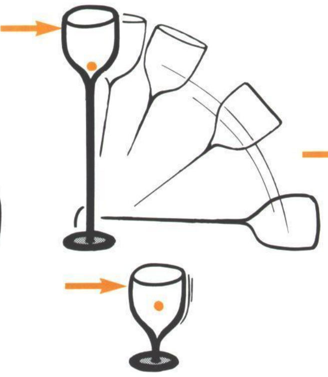

Figure 6. An object is more stable if the centre of gravity is low than if it is high.

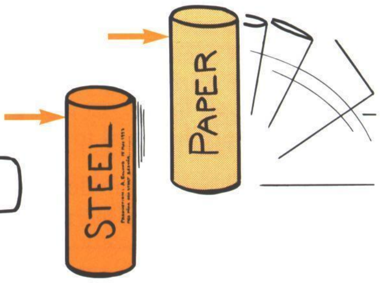

Figure 7. An object with a great weight is more stable than an object with a small weight.

Stability of the human body

Mechanical principles underlying the behaviour of rigid objects as discussed above can be applied to the study of the human body's state of balance in any position it may adopt. As for any object, the stability of the human body will therefore increase when the area of the base of support is increased. The upright human body is least stable when the feet are parallel and close together. As the feet are moved apart and the base is broadened, the person becomes less likely to fall (Figure 8). As an example, you may recall the wide stance assumed by persons standing on a moving bus or train, or on the deck of a ship which is rolling. The base of support may also be increased, and more stability achieved, by the use of a support, such as a walking aid (Figure 9).

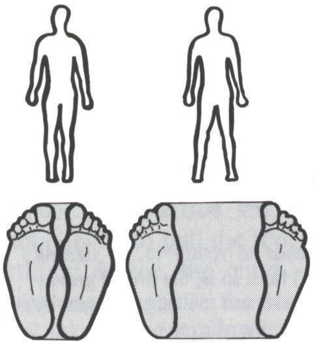

Figure 8. A person can broaden the supporting area to secure stability.

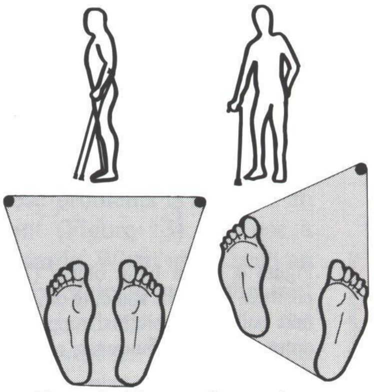

Figure 9. The use of a crutch or cane will greatly increase the base of support and thus the stability of a person.

The base of support of the human body changes during movement depending on the activity involved. When a person is carrying a heavy weight, the body shifts in the opposite direction in order to compensate; in this way the centre of gravity of the combined mass is maintained in a central position over the feet (Figure 10).

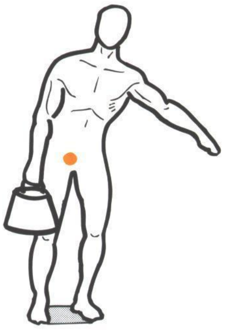

Figure 10. The body is shifted so that the combined mass is in a central position over the base of support. If the load is heavy, the opposite arm is automatically lifted to help counterbalance weight.

Balancing the centre of gravity of the body over the feet requires no conscious thought or effort for the ordinary person. However, for patients with muscle weakness of the trunk and lower limbs due to spinal cord lesions, polio or other conditions, body balance becomes a critical problem. The slightest miscalculation may result in a fall.

Speed of movement is closely associated with requirements for balance. It is easier to balance on a bicycle when it is moving fast than when it is travelling slowly. In the same fashion, patients with difficulties in securing their balance may hurry along in order to decrease the requirements for stability. It may be difficult for some patients to slow down their speed and it may even be helpful to some patients to move a little faster if this can be done with safety.

Pressure

If you push your fist into the palm of the opposite hand you can withstand considerable force without discomfort. The same amount of force exerted by pushing your thumb into the palm becomes painful, while an equal force exerted by the point of a needle would be disastrous. This example illustrates how the "effect" of a force depends on the area of contact. We call this "effect" **pressure.** As found in the example, pressure increases when the contact area is made smaller. We also know from daily life that pressure can be increased by applying a greater force.

Pressure is defined as the total force applied per unit area, which may be expressed by the equation:

$$P = F/A$$

where P is the pressure, F the applied force and A the area over which the force is applied. The SI unit of pressure is the Pa (pascal). 1 Pa equals the force of 1 N applied over the area of 1 m^2, meaning that 1 Pa = 1 N/m^2. This is a rather small unit and for most practical purposes pressure is therefore expressed in decimal multiples of the pascal, such as kPa ("kilo-pascal" = 1000 Pa) and MPa ("mega-pascal" = 1 000 000 Pa).

Using the equation above, we can calculate the pressure of any force where the contact area is known. The pressure of a 2-ton elephant[2] (Figure 11), for example, when standing on one foot with the area of 0.1 m^2, is:

$$P = F/A = 20\,000 / 0.1 = 200\,000\ N/m^2 = 200\,000\ Pa = 0.2\ MPa$$

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[2] The weight of a 2000-kilo elephant is 20 000 N.

This may be compared to the pressure exerted by a 50-kg woman[3] at heel-strike (Figure 12) when wearing spike heels of 1 cm^2 (= 0.0001 m^2) area, which is:

$$P = F/A = 500/0.0001 = 5\,000\,000\ \text{N/m}^2 = 5\,000\,000\ \text{Pa} = 5\ \text{MPa}$$

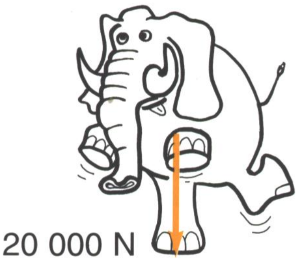


Figure 11. A 2-ton elephant standing on one foot exerts a pressure of 0.2 MPa ....

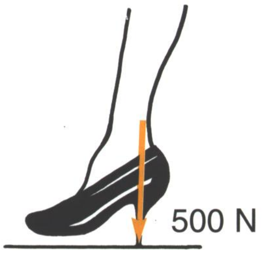


Figure 12. .... while a 50-kg woman in spike heels at heel strike exerts a pressure which is 5 MPa, i.e. 25 times greater!

Though the woman has considerably less weight than the elephant, she exerts a pressure 25 times greater (!), which, of course, is a result of the contact area of a spike heel being so much smaller than of an elephant's foot. (It seems that, if you are careful about the floor at home, you had better invite an elephant than a woman in spike heels....)

Pressure in prosthetic and orthotic fitting

Pressure is a critical factor in prosthetic and orthotic fitting. The forces involved may be considerable, sometimes even greater than the body weight. To reduce pressure, and thus avoid pain and possible injury to the skin, forces exerted by the appliances need to be distributed over as large as possible an area of body surface. In orthotic fitting, for example, the bands of a caliper should be made as wide as possible (see example in Figure 14 below). In the fitting of lower extremity amputees, and especially those with ischial weight-bearing prostheses or end-bearing stumps, the socket must be carefully designed so that the contact force is distributed over a large skin area and not limited to some few bony prominences only. Incorrect design, resulting in high pressure on small body surfaces, may lead to skin breakdown, pressure sores and ulcerated areas, which are serious clinical complications that may delay the fitting, or even make it impossible to accomplish.

Apart from proper design of the appliance, the softness and elasticity of the material supporting the body surface is an important factor in avoiding damaging effects of high pressure. When a force is exerted against the body surface by *rigid materials*, such as wood or metal, pressure may be concentrated in the area of bony prominences. *Softer materials*, such as felt, padding or sponge rubber, allow for better equalisation of the pressure over the entire contact area and may therefore protect the skin over the prominences.

Three-point pressure system

Almost all orthotic devices use what is called a *three-point pressure system* to apply the corrective forces on the body. A three-point pressure system can be described as two forces pressing against a body part opposed by a third force located between the first two (Figure 13).

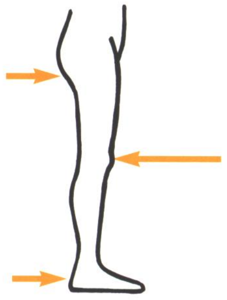
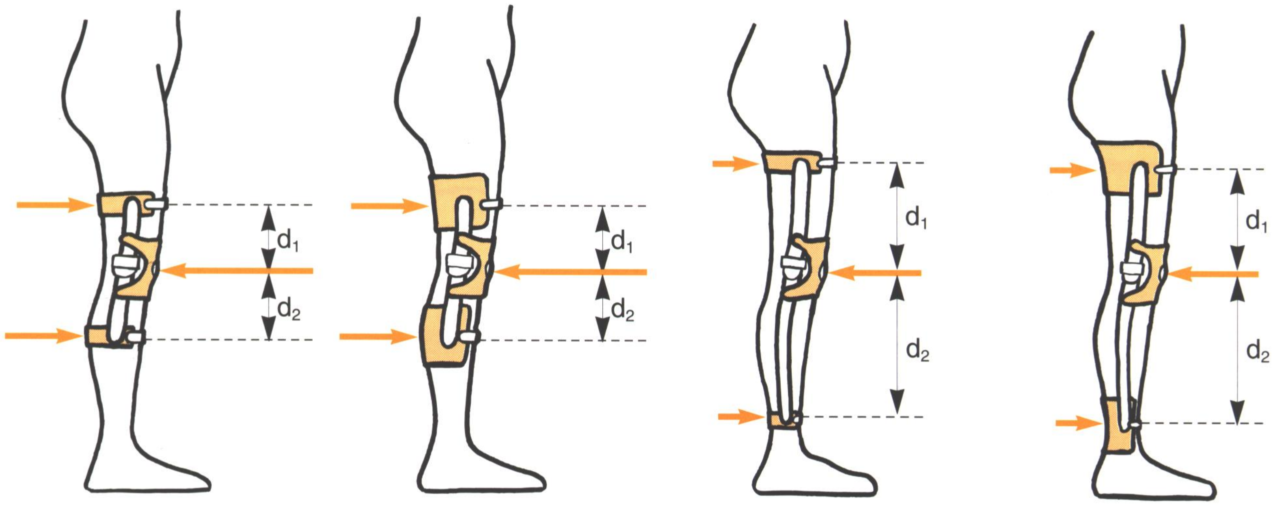


Figure 13. Three-point pressure system stabilising a knee joint. The single opposing force is equal in magnitude to the two forces acting in the same direction.

To avoid skin problems, the pressure applied by an orthosis should be minimised. This may be accomplished by either decreasing the force applied or increasing the area over which it is applied (Figure 14).

[For an example of the use of three-point pressure systems, see separate article in this issue about the treatment of clubfoot.]



A - Short lever arms, small contact area. Heavy pressure!

B - Short lever arms, large contact area. Less pressure.

C - Long lever arms, small contact area. Less pressure.

D - Long lever arms, large contact area. Light pressure!

Figure 14. A knee orthosis (A) provides a three-point pressure system to prevent an unstable knee bending. The lever arms (d_1 and d_2) of the orthosis are very short, and relatively high corrective forces are needed to prevent flexion of the knee (the shorter the lever arm, the higher the force needed). The surface area of the calf bands is also small, resulting in relatively high pressures being exerted on the skin. The pressure on the skin may be decreased by increasing the surface area of the calf bands (B), by increasing the length of the lever arm of the orthosis thus decreasing the corrective forces needed (C) or, ideally, by changing both (D).

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[3] The weight of a 50-kilo woman is 500 N.

Get to know the international discussion in the field of prosthetic and orthotic services in developing countries!

International conferences are held regularly to discuss different aspects of orthopaedic technology in developing countries. These meetings gather participants from different countries, with different backgrounds and with sometimes very disparate views on how to run and further develop prosthetic and orthotic services. The discussions are often fruitful and the recommendations which emerge from the conferences are often useful guidelines on how services could be improved. Studying the reports from such meetings is of interest for anyone dealing with orthopaedic technology, whether with practical work or management issues. Reports from three major conferences that have been held in recent years are:

- Report of *ISPO Consensus Conference on Appropriate Prosthetic Technology in Developing Countries* held in Phnom Penh, Cambodia 5 - 10 June 1995. The conference included presentations from several international organisations and dealt with areas such as manufacture, education, management and project evaluation. Requests for free copies should be addressed to: Mr Norman A. Jacobs, President-Elect, ISPO, c/o National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, Curran Building, 131 St James' Road, Glasgow G4 0LS, UK.

- Report from *La formation francophone des ortho-prothésistes en Afrique - bilan et perspectives*, a seminar held in Lomé, Togo 20 - 24 November 1995 with participants active in the two fields of orthopaedic technology and CBR. The seminar included presentations from 12 French-speaking African countries and highlighted training issues as well as the linkage between prosthetic and orthotic services and CBR. The report, which is available in French only, can be ordered from: Handicap International, Secteur Ventes, 14 Avenue Berthelot, F - 69361 LYON CEDEX 07, FRANCE. The price is 50 FF + postage.

- Report from *International Conference on Orthopaedic Technology* held in Wuhan, People's Republic of China 4 - 9 November 1996. The conference covered four main fields; rehabilitation as part of Primary Health Care (including CBR), finance, education/training and appropriate technology. The conference produced the *Wuhan Declaration*, a recommendation for future work in orthopaedic technology projects. Copies, of both the complete report and the Wuhan Declaration, are in press and will be available free of charge from: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Health - Population - Nutrition Division, Postfach 5180, D - 65726 Eschborn, GERMANY.

Note. The reports can *not* be ordered from ORTHOLETTER, but only from the addresses indicated above.

Learn more about CBR!

Essential CBR information resources is a new publication providing a list of key readings in Community-Based Rehabilitation (CBR) for developing countries. It contains details of books, articles, manuals, videos and other useful resources, together with information on how to obtain them. Copies of *Essential CBR information resources* are available free to developing countries and for £5 / US$10 elsewhere from: Appropriate Health Resources and Technologies Action Group (AHRTAG), Farringdon Point, 29-35 Farringdon Road, London EC1M 3JB, UK.

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WORLD HEALTH
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ORTHOLETTER is published twice a year by the
Department of Biomechanics and Orthopaedic Technology,
University College of Health Sciences, Jönköping, Sweden
WHO Collaborating Centre for Orthopaedic Technology

For a free subscription, please write to the following address:
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Editor in chief: Tommy Öberg Editor: Anders Eklund

ISSN 1103-632X

Issue number 7 - May 1997