ORTHOLETTER

A NEWSLETTER ON ORTHOPAEDIC TECHNOLOGY IN DEVELOPING COUNTRIES

Issue 1 - 1994

New development:

Low-cost polypropylene prosthesis

Polypropylene is a durable thermoplastic material which has proven to be very useful within both prosthetics and orthotics. For many years it has been used in the production of braces and spinal orthotic devices. More recently, it has been successfully tried in the production of prosthetics. As compared to polyester, it is easier to handle and to store and it requires less additional materials in its usage. It has also the advantage of being recyclable, which means that the material can be heated and completely reshaped several times. This has opened up a new possibility, as scrap material from the socket production can be used to produce prosthetic components.

At the Prosthetic Orthotic Centre, POC, in Addis Ababa, Ethiopia, below and above knee prostheses are almost entirely made of polypropylene. The components, i.e. knee joints and alignment devices, are locally produced in aluminium moulds. Thus, the cost of the prostheses is radically reduced, making it possible for more amputees to benefit from the service. .... page 2

Biomechanics in Prosthetics and Orthotics (1)

Biomechanics is the scientific study of biological systems, such as the human body, by the methods of mechanical engineering. For everyone working in the field of rehabilitation, biomechanics forms an important part of the daily work. Whenever patients are given exercises or fitted with braces or prostheses, their bodies are under influence of various forces. The forces applied by rehabilitation staff, whether by hand or through orthopaedic appliances, should support the patients and help them to function better, but if applied wrongly they can also do harm. To guarantee a good rehabilitation of prosthetic and orthotic patients, an understanding of the basic principles of biomechanics is important to everyone involved in the fitting and the functional assessment of orthopaedic appliances.

This issue of ORTHOLETTER presents the first article in a series on biomechanics. Before going into the solution of biomechanical problems, it is necessary to define certain terms which are frequently used in mechanics. What are *force*, *mass* and *weight* for example? These terms are often used in everyday language and we have a good idea what is meant when we hear them. In mechanics however, they are used in a particular way. In this, the first part, we will also become familiar with the three laws of Newton - the laws on which the whole science of mechanical engineering is based.

In the next issue we will, among other things, study different *force systems* and see how a number of forces acting in different directions can be balanced by one single force, the *resultant*, which we also will learn to determine. .... page 6

Next issue:

Hansen's Disease (leprosy)

What is Hansen's disease, how does it affect the body and how is it transmitted? Can it be cured? What can be done in the way of technical orthopaedics? We will read about it in the next issue of ORTHOLETTER.

Biomechanics in Prosthetics and Orthotics (1)

Mechanics can be described as *the study of forces and their effects*, i.e. how forces act on a body and how the body moves (or remains in its position) as a result of the acting forces. ***Biomechanics*** is the study of the mechanics of *living things*, such as the human body. The human body is acted upon by many different forces which can lead it to moving, remaining at rest or being placed under harmful stress and strain. Some of these forces are generated *inside* the body, such as those produced by muscle contractions. Others are *external*, such as *gravity* and those manual or mechanical forces used by a physiotherapist when giving a patient exercises. The external forces also include some forces of particular interest in the prosthetic and orthotic fields, namely those acting upon the human body through orthopaedic appliances.

Mechanics can be divided into two branches: *dynamics*, which deals with bodies in motion, and *statics*, which deals with bodies remaining at rest. Since the problems we want to study in prosthetics and orthotics may often be satisfactorily idealised to be valid under *static* conditions, the present text will focus on *problems in statics* and their solutions.

Definitions in mechanics

Units

The world around us consists of different objects (or bodies), which we can refer to as being "big", "small", "heavy" or "light", etc. To be more accurate, we can *measure* the objects and tell their exact length or weight. Accurate measurement is often important, but would be of little use if we had not agreed on common **units** for the quantities we are measuring. An international uniformity has been achieved through the introduction of the International System of Units, abbreviated SI. SI units of some of the quantities we will deal with in our biomechanical studies are shown in the table:

Quantity	Unit name	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Force	newton	N

Table 1. SI units

Force

Force is one of the basic terms in mechanics. We are all familiar in general terms with the concept of force, but it is difficult to define. To produce a force, it is always necessary for one body to act upon another. This action may result in a pull (tension) or a push (compression) (figure 1). Forces may also act between bodies at a distance and not in contact with each other, such as the *force of gravity*, which is one of the most obvious forces, since it is acting upon all bodies on earth (figure 2).

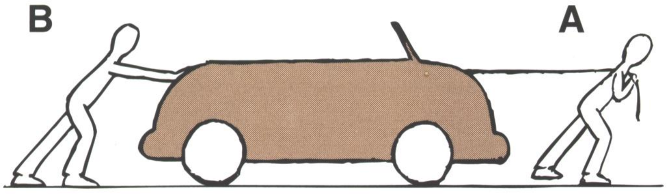


Figure 1. A body acting upon another may result in a pull (A) or a push (B).

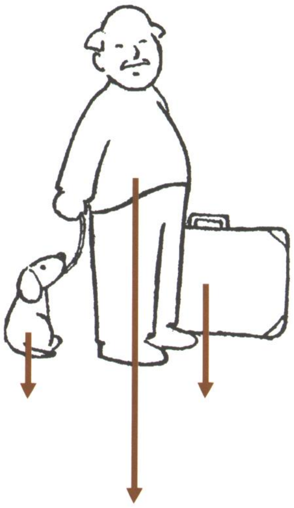


Figure 2. The gravity of earth pulls the objects downwards.

Another thing that we can say about a force, is that it is not completely described if we know only its *magnitude* (size). A force of 50 N acting *downwards* on a body may produce a completely different effect from that of a 50 N-force acting in the *horizontal* direction (figure 3). Thus, in addition to its magnitude, the *direction* of the force must also be known. A quantity which has both magnitude and direction is called a *vector quantity*. (This is in contrast to *scalar quantities*, such as temperature or time, which are completely described by the magnitude; 20°C or 5 seconds, for instance, cannot have a direction.). A vector is graphically represented by an arrow (figure 4). The length of the vector shaft is proportional to the magnitude of the force and the arrow head indicates the direction of that force. This way of drawing vectors enables forces to be visualised, and, as we will see later, it also enables us to graphically analyse systems of forces and thus to find solutions to biomechanical problems.

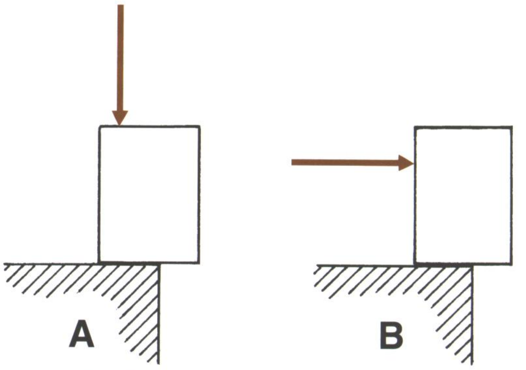
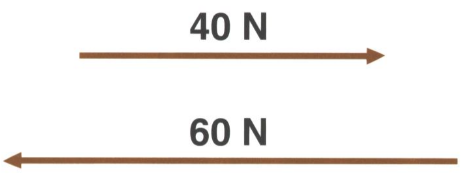


Figure 3. Depending on its direction, the force will produce different effects. In A, the body will remain in its position. In B, it is likely to fall.



Scale: 1 cm = 10 N.

Figure 4. The length of the vector shaft is proportional to the magnitude of the force. (In the chosen scale, these vectors should have a length of 4 and 6 cm respectively.)

Mass and weight

All objects contain *matter* ("material"). The amount of matter contained in an object is called the **mass** of the object. In everyday language we use the terms *mass* and *weight* to mean much the same thing. In scientific terms however, there is a clear distinction between them. **Weight** is a *force*, namely the force exerted by gravity on the object (figure 2). As long as we stay on earth, within the gravitational field, we will not be able to see the difference between mass and weight; all objects have both mass and weight and the higher the mass, the higher the weight. If we were to travel in space, however, we would find that all objects were "floating" in a *weightless* state. Without the gravitational pull, the objects will lose their *weight*. Still, they contain the same amount of matter as if they were on the ground, i.e. they still have the same *mass*. And you may be sure that if someone throws a rock at you in space, even though the rock doesn't weigh anything, you are still likely to be injured!

Centre of gravity

Although the mass of any object is distributed throughout every part of it, it is frequently convenient, as far as the effects of force are concerned, to imagine that the whole mass is concentrated at a single point, which is called the **centre of gravity**. A rigid object behaves as if gravitational pull concentrate all its force at this point (figure 5). For a regular shape, such as a cube, made of a uniform material , it is easy to see that the centre of gravity must be at the geometric centre (figure 6). However, for irregular shapes, such as the human body, it may be necessary to determine the centre of gravity by direct measurement. It is frequently stated that the centre of gravity of the human body is just in front of the lumbosacral junction (figure 7). This is approximately true for a person standing, but with every change in body position the centre of gravity changes. If weights are added to the body, as when carrying a box, the centre of gravity of the total system will have to be reconsidered (figure 8). Likewise, loss of a body part through amputation also alters the location of the centre of gravity. It is not even necessary for the centre of gravity to remain within the body - the centre of gravity of someone bending down to touch their toes will usually be outside the body (figure 9).

Figure 5. The centre of gravity is a point at the exact centre of a body's mass. A rigid object behaves as if gravitational pull concentrate all its force at this point.

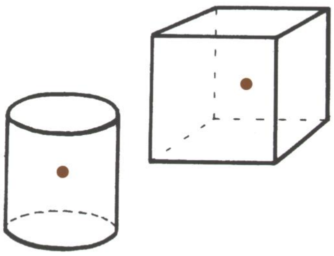


Figure 6. In a regular body, the centre of gravity is located at the geometric centre of the object.

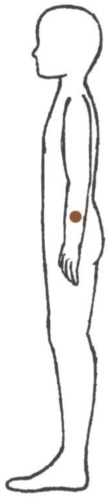


Figure 7. The centre of gravity when standing.

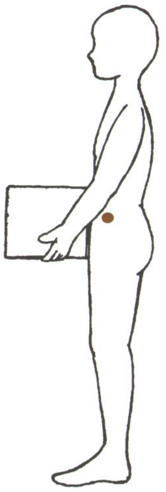


Figure 8. When carrying a box, the position of the centre of gravity (for the body and the box together) will be more to the front.

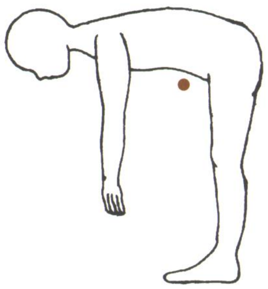


Figure 9. The centre of gravity is usually outside the body when bending.

Newton's three laws

The whole science of mechanical engineering is based on the three laws formulated near the beginning of the eighteenth century by the English scientist Sir Isaac Newton. The principles themselves are quite simple and readily understood, but their application to the solution of problems may become more difficult. The laws state that:

1. *A body will remain at rest or in uniform motion until acted upon by an external force*. This means that if a body is *at rest*, the forces acting on it are completely balanced and an external force must be applied to change this state. If a body is *moving*, it will continue to move, at the same speed and in the same direction, until some force causes it to stop moving or to change its speed or its direction. We have all experienced this while riding in a car; if the driver suddenly brakes, the body tends to continue forward (at the same speed as the car had at the previous moment) until the safety belt or the hands

and arms (the *external force*) cause it to stop (figure 10). In a quick turn, the body tends to continue in the previous direction and is therefore pushed by the inner side of the car (the *external force*) to change the direction (figure 11). The property of a body which makes it resist a change in motion is called *inertia*. The first law is consequently sometimes called *Newton's law of inertia*.

2. *An external force will cause a body to accelerate in the direction of the force. The acceleration* (the change in speed per second) *is proportional to the force and inversely proportional to the mass of the body (a = F / m).* Put simply, this means that a large push on a small object will accelerate it rapidly, whereas a small push on a large object will accelerate it slowly (figure 12). (The first law is actually a special case of this one; when the forces acting upon the body are balanced, it will remain at rest or in uniform motion.)

3. *For every action there is an equal and opposite reaction.* This means that whenever two bodies are in contact, the body being pushed will push back just as hard as the body doing the pushing (figure 13).

(To be continued in the next issue.)

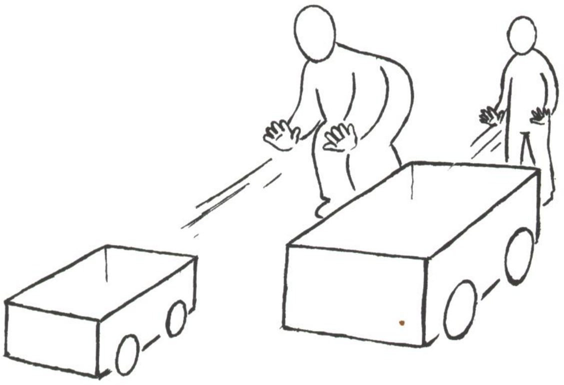


Figure 12. A large push on a small object will accelerate it rapidly, whereas a small push on a large object will accelerate it slowly.

Figure 10. The body continues at the same speed.

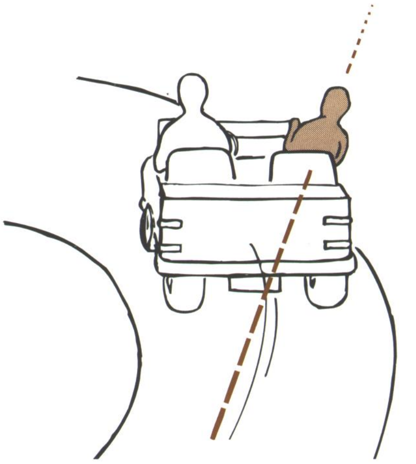


Figure 11. The body tends to continue in the previous direction.

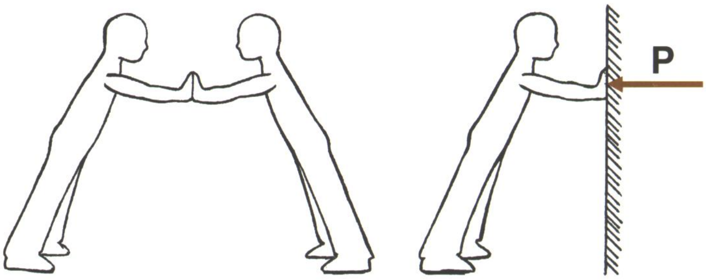


Figure 13. A push must be opposed by an equal and opposite push, as illustrated by the two figures. The equal and opposite push by the wall (P) is not as easy to see but it is just as real.

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