Taking the strain — the ergonomics of water carrying

by Ben Page

No kitchen taps, no village waterpump, just a long trek to the nearest water source. Can ergonomic studies make women's burdens easier to bear?

CARRYING WATER AND firewood have long been recognized as among the most arduous of tasks in the developing world. It takes up considerable time and energy, and has long-term effects on health, both as a result of making demands on the metabolism not met by the nutritional intake, and by regularly putting an excessive strain on the skeleton, leading to spine deformities and the early onset of arthritic diseases. These problems affect women in particular, as they usually bear the brunt of the work.[1]

Trying to reduce the drudgery of water collecting has generally involved bringing the point of water collection closer to the user by providing new sources. There are some places, however, where this will take a long time to achieve, or is totally impossible. In these circumstances, the use of animals[2] or wheeled devices[3] is recommended.

Paul Harris

Perfectly balanced — the women of Jaisalmer in Rajasthan prepare for their journey home.

Few options

But sometimes, even these options are impractical: haulage animals are expensive to buy and feed, and even when they are financially viable, members of the family are likely to compete to use them for other tasks. Wheeled vehicles may be useless on steep and rugged paths.

As they have done for centuries, therefore, some people still have to carry water themselves. There is a familiar array of traditional water-carrying devices common in the South (head-loads, yokes, and *chee-gehs*) — and the growing armies of Northern backpackers travelling the globe have led to extensive research into rucksack design — but a method for comparing the relative value of different techniques in the context of water-carrying is not so well-known.

What does ergonomics tell us?

The tools of ergonomics — defined in the dictionary as 'the study of the efficiency of persons in their environment' — can provide a straightforward and revealing analysis, using a variety of different criteria, such as which device consumes least energy for a task, which device do people feel most comfortable using, and which device adheres most closely to the principles of effective carrying.

Ergonomists and physiologists have been studying the way that people carry things since the middle of the nineteenth century. Much of the initial research was inspired by military demands, as soldiers were expected to carry heavy loads across a variety of terrains. Most of the research conducted this century has focused on the carrying tasks of factory workers. But a small body of literature covering research on the situation in the developing world, can be found in the journal *Ergonomics*.[4]

From this work, we can derive a list of the different variables it is possible to compare when studying a water-carrying task: weight of the load, distance carried, speed and duration, type of terrain covered, gradient of the journey, and carrying device used. Alternatively, it is also possible to focus on the physical characteristics of the person performing the carrying task, their age, gender, nutritional intake, size, fitness, and experience.

Despite the rather large number of variables, experiments can be designed to be relatively simple, with almost no need for specialist equipment. For example, to compare different devices for carrying water in a laboratory setting, we can improvise with broadly similar subjects, whose differences can be allowed for, and then set them a fixed task, within a controlled environment, to be carried out with each device in turn.

Clearly, to pick up accurately all the variable interactions requires a raft of studies, incorporating field as well as laboratory tests but, because of the long history of this work in other fields, much is already known. Furthermore, as the aim of any experiment is to tell us if one carrying device is better than any other, the precise explanation of why it is better, whilst interesting, may not be critical in the applied context.

Testing

Ergonomic tests can be divided into three distinct classes — physiological studies examining the metabolic cost of the task, psychological studies

Principles of effective load carrying

- **Keep the load close to the trunk, both for stability, and because it minimizes the change in the centre of gravity, and so minimizes the muscular action necessary to balance.**
- **Maximize the use of large muscle groups and spread the load between groups.**
- **Allow arms and legs free movement; the gait should be as normal as possible.**
- **Minimize any inhibition of ventilation or constriction of the chest.**
- **As far as possible, the load should be distributed symmetrically, to minimize the muscular effort needed to keep the body vertical.**
- **Maximize the use of those points of contact (such as the hips) which are less sensitive to the pressure of belts and straps.**
- **Distribute the load across as wide an area as possible at the points of contact. Eliminate fabric wrinkles and chafing points.**
- **Minimize static muscle effort (such as supporting the load with a hand) as this can be particularly tiring.**

examining users' subjective preferences, and bio-mechanical studies modelling the forces which operate within the human body during a work task. The first two are simpler and have the longest history; they are the most applicable to any ranking exercise, but they can be hampered easily by non statistically-significant data. Ultimately, the bio-mechanical studies will, in all probability, be the most useful explanatory tool.

Tigray in the lab

Water development in central Tigray, in Ethiopia, is hampered by the absence of available groundwater, and the high altitude of many settlements relative to spring sources. Rainwater harvesting is the people's best option in the long term[5] but, for now, the existing spring sources at the base of the mountains will continue to be used for drinking-water. The paths are too steep and stony for the use of wheeled vehicles and, amongst families that can afford donkeys, the usual priority is agriculture, not transporting water.

At the moment, the rural Tigrayans carry water home in large round pots, supported high on their backs by a rope fastened across the chest. The people conducting the experiments had one clear objective — to find out if there was a better, alternative way of carrying the load. To be sustainable, any new water-carrying device must be cheap, robust, use locally available materials, and be produced within the village. They should also incorporate the principles derived from ergonomists' studies of carrying, shown in the box on the left.

New devices

Given these criteria, three designs were manufactured and tested in the UK. A wooden backframe, a frameless brack-strap, and a frontal yoke made from HDPE waterpiping were compared with each other, and with the existing style of water pot, while volunteers carried 20 litres of water and a 'no load' control (Figure 1). The tests followed the pattern laid out by Legg;[6] they combined looking for differences in metabolic cost, perceived exertion, postural discomfort, and variation in gait. Four healthy, young, English women agreed to participate in the study. In order to establish the subject's relative fitness, and the linear relationship between heart-rate and oxygen consumption, her mean, maximal oxygen uptake was calculated on an oscillograph as she rode an exercise bike, wearing an oxygen mask. This information can, however, be estimated from a nomograph.

The women were asked to climb up and down a step for 25 minutes, at their own speed, which was recorded in steps/minutes. They were then asked to change to the speed they thought they would be able to keep up for eight hours. Their heart-rate (from which their oxygen consumption was inferred) was recorded every five minutes, and measurements were taken of the women's exertion and postural discomfort. After the step test, each volunteer stood in a tin of paint and then walked across two sheets of paper; the resulting footprints enabled the researchers to calculate the average pacelength under different load conditions.

Results

The results, illustrated in Figure 2, show that both the women's consumption of oxygen, and their speed varied, masking any differences between the devices. To allow for this, a distance was fixed and the resulting energycon-sumption is expressed in litres of oxygen consumed during a 100m climb/kg body-weight. This rather unwieldy unit reflects the fact that there were significant differences in the subjects' body-weights. The results indicate that all three new designs show a statistically significant improvement on the traditional system, although there is no significant difference between the designs themselves.

These results were reinforced by the subjective measures of postural discomfort and specific pain, which were quantified by asking the four women to put themselves on a standard scale of exertion (Borg's), and by locating and scoring pain on a map of the body (Corlett and Bishop Bodymap). The results were not statistically significant. The gate measurements showed that the Tigrayan pot and the frontal yoke produced a significant difference from the normal pace, contradicting one of the basic design principles. On the basis of these results, we can say that the potential exists to make water-carrying less arduous for Tigrayans.

In the real world

Of course, this research raises as many questions as it answers. First, there are those who challenge its accuracy: can English volunteers really 'stand in' for Tigrayan women? What effect does training/experience have? How good an indicator of comfort is speed? Further research — preferably in the field, in which the users participate — is needed.

A second set of questions, which challenges the fundamental value of this approach, is more difficult to answer. Would potential users switch to a different way of carrying if they had the choice? In how many contexts is the effort involved in persuading people to change their traditional practices justified? Is there a danger of exaggerating the importance of what was intended as a stop-gap ameliorating measure? Would working on nutrition be a more effective way of making the task easier?

Carrying 20 or 30kgs of water up a hill is going to be hard work however much effort is put into making it easier but, having shown in a laboratory that it is possible to make the task more comfortable, it must surely be worth seeing whether it is borne out in the reality of the field. If so, the next test will be to see whether the potential user group is impressed enough to adopt — and adapt — the new technology.

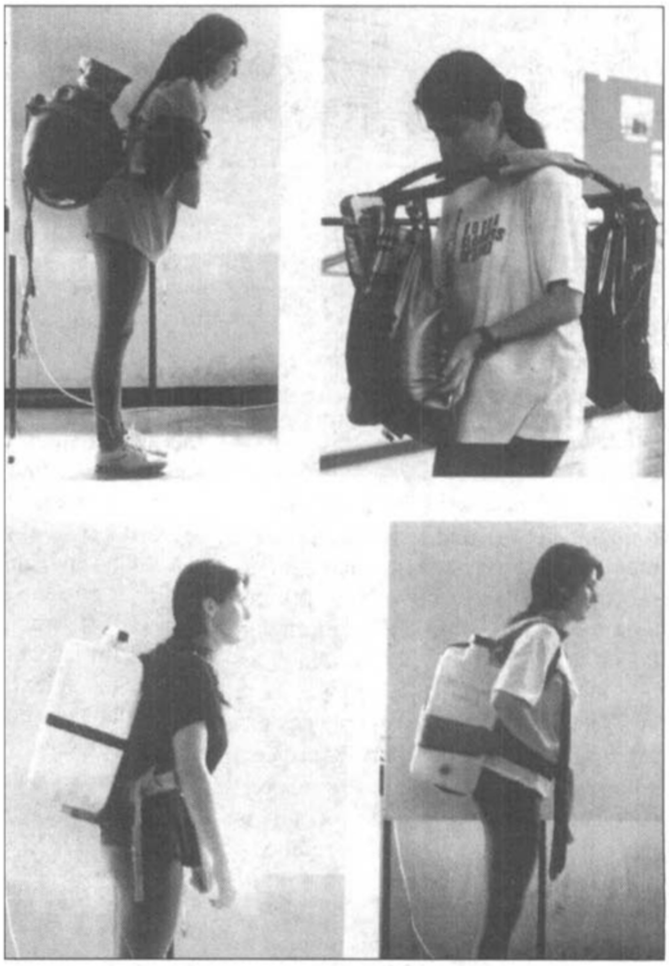

Figure 1. The volunteer's load is a heavy one. Clockwise from top left: the Tigrayan pot, the frontal yoke, the backstrap, and the backframe.

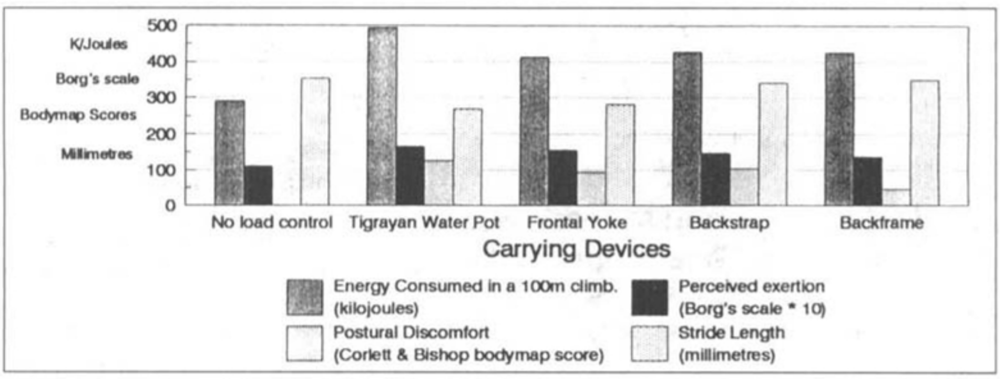

Figure 2. Differences in metabolic cost, perceived exertion, postural discomfort, and stride for a fixed task — how the four devices compared in the laboratory.

References

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