Background information on running analysis

Ever since the jogging boom of the 1970s, and with greater intensity since the start of today's running boom, scientists have grappled with the question as to which factors can raise or reduce the not insignificant risk of injury from running.

While much research is still in progress, most scientists today are agreed that there are three requirements which a good running shoe must fulfill:

- good damping of the foot's impact on the ground
- good support of the foot (control of the degree of pronation)
- straight ahead orientation of the foot

The shoe industry today offers a wide variety of different running shoes with very different properties. An important criterion when recommending a running shoe is that it should optimally match its wearer's running style.

Damping should be no greater than necessary, since strong damping makes a shoe unnecessarily thick, distancing the foot from the ground. This increases the leverage and thus the risk of ankle sprain, a common type of injury among runners, especially when running cross-country.

Pronation is the word used to describe the natural inward inclination of the foot when it strikes the ground. This movement is normal and indeed essential for a natural running pattern. If the degree of pronation is too small, this is termed supination, whereas if it is too large, one speaks of overpronation. Thus, supinators run more on the outside, while overpronators run more on the inside of their feet. As a means of checking the degree of pronation the shoe can be fitted with what is referred to as a pronation wedge. This is a wedge-shaped section on the inside of the throughsole which is made of a harder material, thus limiting the degree of pronation. If a normal runner, or worse still, a supinator is given a shoe of this shape, it will disturb his natural running pattern and most probably lead to physical complaints.

The foot's straight-ahead orientation is facilitated, amongst other factors, by a well-fitting heel cap and by the length of the pronation support. Here too, corrective measures should only be considered if the runner's motion profile deviates from the normal.

Over time it has transpired that the resulting running pattern depends on the individual runner as well as on the shoes he or she is wearing. The two form a functional entity which can only be assessed as a whole. The forces acting on the foot in standing give sensory input signals to the body. In response to this the body adapts its muscular activity with the aim of keeping its motion profile as constant as possible. If the structure of the shoe matches the runner's motion profile, his muscular activity will decrease; if not, it will increase. In other words, the shoe acts on a control loop which can be very different from one person to another. This means there can be no such thing as an ideal shoe, but rather that the shoe must match its wearer. Research is currently engaged in exploring what consequences can be drawn from these observations.

To make a good shoe recommendation it is necessary to know not only the properties of the shoe but also the user's running style. The following section gives a brief overview of the various methods of running analysis that are currently on the market.

Indirect methods of running analysis

Indirect methods have the drawback that the effect of a shoe on the wearer's running style is deduced indirectly rather than being measured directly. This involves making assumptions which, as stated before, must always be regarded with reserve in biomechanics. In the following the effect of a shoe with a wedge extending the length of the entire sole will be discussed as an example. If the thin side of the wedge is oriented inward, one would expect all test persons to show a markedly greater degree of

pronation. In fact however, this effect was only found in some test persons, whereas others showed no change and still others showed a diminished degree of pronation.

Foot scanner

This purely static method consists in scanning the runner's footprint in standing. It provides information on the contour of the foot and on any anomalies such as pes valgus or high-arched foot. From the contour one can determine the length and width of the foot and thus narrow down the choice of shoes. However, there is no way around trying on a shoe to tell whether it fits.

Contrary to widespread opinion it is not possible to infer a person's running style from his or her footprint or leg axis alone. Scientific studies have shown that foot anomalies of every kind are to be found across all running style categories, albeit with different relative frequencies. An individual's motion profile itself shows variation, so much so that it can change entirely from walking to running even if he is wearing the same pair of shoes. Therefore there is little value in trying to determine a person's running style merely from the way he or she stands.

Direct methods of running analysis

Direct methods are aimed at measuring and analyzing factors of interest as directly as possible under real-life conditions.

Pressure measurement plate

This method consists in measuring plantar pressure distribution as the test person walks or runs over a pressure measurement plate. The accuracy of measurement depends on the number of sensors used. The test person must be barefoot, since measurements performed with shoes on yield little information. A suitable running track with foam rubber padding is required, since on hard ground runners tend to run only on the balls of their feet. The measured data are usually displayed in the form of a pseudo-color image with color-coded pressure intervals.

This time and money consuming method is best left in the hands of scientists. Interpreting the images requires a good deal of knowledge and experience. The method is especially suitable for determining the gait line and pressure peaks, less so for measuring pronation. Large-sized pressure measurement plates are far too expensive for most retailers to use for running analyses, whereas small-sized plates are difficult for the runner to hit squarely.

Video analysis

With this method the test person is normally filmed from behind while running on a treadmill. Then the video is played back in slow motion. The maximum pronation angle is determined by measuring the angle in a fixed image defined by markers applied to the test person´s heel cap and leg during running with maximum pronation (ß angle). The method does not allow determination of the impact force.

By contrast, angle measurements performed by video analysis are very precise. Unfortunately however, this parameter has been found to vary widely under identical conditions, and the method is therefore no longer used for research. This is also due to many other reasons.

One problem is the parallax error which always occurs when the runner is filmed while running at an oblique angle to the camera. It only takes deviations of a few degrees to produce significant measurement errors. Furthermore, the measurement of angles in any plane that is not exactly perpendicular to the direction of the camera is also liable to produce errors on account of the two-dimensional projection. Another problem is the low measuring frequency of video photography. Pronation reaches its maximum within 30 – 50 ms. This time interval allows for no more than 1 – 2 video images, making it impossible to tell whether the moment of maximum pronation has been captured. An additional problem is the relative shift between points that is caused by the movement of the skin on which they are marked.

Besides these measuring errors video photography also poses problems when it comes to interpreting measurement results. The pronation angle influences both the position of the heel cap and the leg axis. This in turn has a dramatic influence on the apparent pronation angle in bow-legged or knock-kneed runners. Bow legs produce exaggerated pronation values, which can mislead the consultant into recommending shoes with pronation support. This type of shoe will make the runner run even more on the outside of his feet, thus increasing his risk of injury.

A further problem is the necessity of using a treadmill. Even experienced treadmill runners show a different motion profile on the treadmill than they do on firm ground, not to speak of novices. At least the salesman must keep a close eye on his customer on the treadmill so as to support him if he should fall.

Achillex

Achillex was designed from the outset as a system that would not only permit scientifically founded analyses and shoe recommendations but also be easy to use in practice. The idea was furthermore to avoid the problems of the systems named above.

From this it followed that the system would need to be able to measure the impact force, the degree of pronation and the orientation of the foot under natural, real-life running conditions at high measuring frequency. This was achieved with Achillex as follows:

Measurement of impact force: Measurement of tibial acceleration is considered to be the most direct way of measuring the impact force. Achillex measures acceleration not directly at the tibia (shinbone) but at the leg. Studies have shown that, given sufficient resolution, these parameters yield equivalent values.

Degree of pronation: Both the angle and speed of pronation are suitable for providing meaningful information on pronation. Achillex uses gyroscopes to measure and evaluate the speed of pronation directly at the heel cap, i.e. without reference to the leg (termed the γ angle). This helps to circumvent the above-mentioned problems with the leg axis.

Orientation of the foot: The orientation of the foot can be inferred from the pronation curve. A straight-ahead orientation is indicated by the absence of rotation, i.e. zero angular velocity of the heel cap.

Time resolution: Achillex measures at a frequency of 400 Hz (400 measurements per second) At the highest possible angular velocity of 20 rad/s this gives a maximum change of angle of 2.85 degrees per four hundredths of a second, while at a normal angular velocity of 7 rad/s the resolution per shot is 1 degree. For a correct representation of very fast pronation movements a recording frequency of at least 200 – 250 Hz is required.

Calculation of averages: Achillex automatically measures several steps. The first and last step of a sequence are not considered, nor are irregular steps. The average of all valid steps is calculated automatically. This ensures that the outcome is not distorted by deviations in individual steps.

Natural conditions: The purpose of Achillex is to provide information on running, so what it does is to measure running. Not only is there no treadmill, but the customer can also run at the speed he or she chooses.

Ease of use - Achillex comes with an online evaluation unit which automatically guides the runner with voice messages as he or she runs. The runner's motion is continuously analyzed and screened for evaluable steps. Measurement ends automatically when enough steps have been recorded.

Achillex is the first system on the market to permit fully automated analysis and interpretation of personal running styles. It includes a fully automated expert system which generates a shoe recommendation on the basis of the identified running pattern. In its stand-alone version Achillex does not depend on a PC for the evaluation. In this way all its functions are available at any desired place.

Determination of shoe properties

Up to now, determining the properties of a shoe was an involved procedure. In addition to the testing of materials this normally included practical wearing tests and / or biomechanical tests. The result was either published in the form of a shoe test or entered in a product-specific database. Whichever option was chosen, it remained that the test outcome of was not readily transferable from one person to another. A shoe which has been found to be good need not necessarily be optimal for every runner within its designated user group.

For this reason a two-stage selection procedure was developed for Achillex. In the first stage the runner's motion profile is determined with a neutral and plain but cushioned shoe. The results then serve as a basis for identifying a suitable group of shoes. In the second stage, comparative measurements are performed to analyze the influence of the selected shoe on the runner's motion profile (impact force and pronation).

Practical wearing tests

The purpose of practical wearing tests is to gather and average subjective assessments. There have been scientific studies aimed at identifying factors which primarily determine a tester's subjective assessment. It was found that besides the overall fit of the shoe the tester's assessment depends to a large degree on the maximum acceleration at the moment of ground contact. This is a parameter which Achillex measures reliably. By contrast, pronation, regardless of whether it is measured or felt subjectively, appears to have no influence on the tester's preferences. In other words, people are unable to sense the degree of their pronation. Instead they probably unconsciously base their choice on the hardness of the impact.

In summary it can be said that practical wearing tests are of limited value and no substitute for well-founded measurements. Objective tests with Achillex are clearly preferable and should be performed for every runner individually.