METHOD FOR INTERPRETING FORCES AND TORQUES EXERTED BY A LEFT AND RIGHT FOOT ON A DUAL-PLATE TREADMILL

This application is a continuation-in-part application of U.S. patent application Ser. No. 10/393,349 filed on Mar. 21, 2003 now U.S. Pat. No. 6,878,100, which claims the benefit of U.S. provisional Application Ser. No. 60/368,807, filed Mar. 21, 2002.

I. FIELD OF THE INVENTION

The present invention relates to a device for measuring force and torque in three dimensions for both the right and left feet during walking and/or running on a treadmill. More particularly, the invention is a method for determining force and torques exerted on each foot in three dimensions during walking and/or running on a treadmill.

II. BACKGROUND OF THE INVENTION

In the event of rehabilitation following any injury or simply in order to monitor and test an individual, it is important to ascertain the forces exerted by each of the legs of the individual when, for example, walking or running normally.

Apparatus is known which can be used to measure angular variations between the tibia and femur corresponding, in particular, to movements of flexion and extension when walking. There are a variety of methods and devices that have been described in the prior art for determining quantities related to the position, magnitude and distribution of vertical forces exerted by a subject's foot (or two feet combined) against a support surface during standing or walking. The three commonly used methods and devices include coupled force transducers, instrumented shoes, and independent force transducers.

A. Coupled Force Transducers

One class of methods and devices for determining quantities related to the forces exerted on a support surface uses a forceplate that typically is a flat, rigid surface that mechanically couples three but more often four linear force transducers. The typical forceplate includes linear force transducers coupled to a substantially rigid plate to form a single force measuring surface, and each provides a way by which the force measuring surface is used to quantify aspects of the forces exerted by the feet of a subject standing on the forceplate. The most commonly determined quantities used to describe the forces exerted on a standalone forceplate surface (i.e., not part of a treadmill) by an external body are the following: (1) the position (in the horizontal plane) of the center of the vertical axis component of force, (2) the magnitude of the vertical axis component of the center of force, and (3) the magnitude of the two horizontal axis components (anteroposterior and lateral) of the center of force. Calculation of position and magnitude quantities for the vertical axis component of the center of force requires that only the vertical force component be measured by each of the three (or four) mechanically coupled force transducers. To measure the horizontal axis components of force, the force transducers must also measure the horizontal plane components of force.

The exact form of the calculations required to determine the above described center of force position and magnitude quantities from the measurement signals of the linear force transducers depends on the number and positions of the force transducers. Specifically, these algorithms must take into account the known distances between the force measuring transducers.

When a forceplate is used to measure quantities related to the position of the center of force, the position quantity is always determined in relation to coordinates of the forceplate surface. If the position of the foot exerting the force on the surface is not precisely known in relation to the forceplate surface, or if the position of the foot changes with time relative to the surface, the position of the center of vertical force cannot be determined in relation to a specified anatomical feature of the foot.

In order to measure forces exerted by the foot, there are known systems which use a platform which rests on the floor and uses sensors. The platform is located along the path that is walked in order to obtain an image of the force exerted by a footstep. Nevertheless, it appears that such a solution is not satisfactory given the fact that the person has a natural tendency to pause (or at a minimum become self-conscious of the need to hit the forceplate and alter their gait) before walking onto the platform so that the force which is exerted is not natural. This system can be duplicated for each leg. This system is not suitable for the measurement of several consecutive steps, because different individuals have their own unique gait.

B. Instrumented Shoe

A second class of methods and devices described in the prior art for measuring quantities related to forces exerted by a foot against a supporting surface during standing and walking is a shoe in which the sole is instrumented with linear force transducers. The principles for determining the position of the center of vertical force exerted on the sole of the shoe by the subject's foot are mathematically similar to those used to calculate the position of the center of force quantities using a forceplate.

Because the position of an instrumented shoe is fixed in relation to the foot, the instrumented shoe can be used to determine the position of the center of vertical force in relation to coordinates of the foot, regardless of the position of the foot on the support surface. A disadvantage of the instrumented shoe is that the position of the center of vertical force cannot be determined in relation to the fixed support surface whenever the position of the foot on the support surface changes during the measurement process. Another disadvantage in a clinical environment is that the subject must be fitted with an instrumented shoe. Another disadvantage is that thin film transducers have been difficult to calibrate and are prone to folding and bending which result in spurious output. Also, only force normal to the film surface is measured, and forces in other directions go unmeasured. Also, because the inside of the shoe is unlikely to be flat, the precise direction of the measured force is indeterminate.

The position and the magnitude of the center of force exerted by a foot against the support surface are determined relative to anatomical features of the foot by embedding force transducers in the shoes of walking and running subjects. Measures of the timing of heel-strikes and toe-offs have been made using contact switches embedded in the subject's shoes.

C. Independent Force Transducers

A fundamentally different method and device described in the prior art for determining quantities related to the forces exerted on a standalone support surface utilizes a plurality of mechanically independent vertical force transducers. Each vertical force transducer measures the total vertical force exerted over a small sensing area. The independent transducers are arranged in a matrix to form a force sensing surface.