

FORCE PLATES

Force platforms or **force plates** are measuring instruments that measure the ground reaction **forces** generated by a body standing on or moving across them, to quantify balance, gait and other parameters of biomechanics.

Force Plates can be used for: Gait, Sport and Balance.

A **force plate** measures the force that is exerted by the ground in opposition to the weight on it. However, a force plate is also able to provide information about the forces exerted parallel to the ground and the location of the force vector. An example of motions with a shear (parallel) ground force component would be walking; the landing and push-off phases of walking each have a vertical force component as well as a horizontal force component. The horizontal force component is parallel to the ground and brakes or accelerates forward motion of the centre of mass.

A **force plate** is an instrument for measuring force. Typically, they are used in biophysics and athletics applications to study the forces involved in human or animal locomotion. A force-plate can either be portable in which case it looks like a giant set of scales or fixed. The force plate has sensors, built into feet of its platform, which constantly measures the take-off force and relays it hundreds of times per second to a computer. The height of jump, jump power and other parameters are automatically calculated from the take off force.

Force plates use load cells to read forces. Load cells use what are called strain gauges, which essentially are variable resistors that change their resistance relative to their strain (basically how much they stretch). By measuring the resistance, and calibrating each load cell so that the resistance is meaningful in proportion to force, you can use linear algebra and some knowledge of statics to figure out what the torques, centre of pressure and Ground reaction force are.

An ideal force-plate should

- i. Be able to resolve the vertical, forward and lateral components of the force
- ii. Have low 'cross talk' between the measured components of the force
- iii. Have sufficient sensitivity and resolution for the subject of interest

- iv. Have a linear response
- v. Have a response independent of where on the plate surface the force is exerted
- vi. Have a high natural frequency of oscillation
- vii. Have sufficient safety margin to protect both the plate and the subject from damage due to failure
- viii. Be Simple and inexpensive

The suggested design is simply a rigid plate surface suspended at each corner by a transducer element. The transducer element is composed of two strain-gauge instrumented spring blades oriented at 90° to each other, the horizontal blade is sensitive to the vertical force, and the vertical blade is sensitive to the horizontal force. The four blades supporting each end of the plate surface are cut out of one solid bar. Each spring blade is modelled as if it were two identical cantilevered beams joined at their distal ends.

Operation

The simplest force platform is a plate with a single pedestal, instrumented as a load cell. Better designs have a pair of rectangular plates, although triangular can also work, one over another with load cells or triaxial force transducers between them at the corners. Like single-force platforms, dual-force platforms can be used to assess performance in double leg tests and strength and power asymmetries in unilateral jump and isometric tests. However, they also provide an additional level of intelligence on neuromuscular status by evaluating the force distribution between limbs during double-limb tests, revealing critical information on strength asymmetries and compensatory strategies.

The simplest force plates measure only the vertical component of the force in the geometric centre of the platform. More advanced models measure the three-dimensional components of the single equivalent force applied to the surface and its point of application, usually called the centre of pressure (CoP), as well as the vertical moment of force. Cylindrical force plates have also been constructed for studying arboreal locomotion, including brachiation. Force platforms may be classified as

single-pedestal or multi-pedestal and by the transducer (force and moment transducer) type: strain gauge, piezoelectric sensors, capacitance gauge, piezoresistive, etc., each with its advantages and drawbacks. Single pedestal models, sometimes called load cells, are suitable for forces that are applied over a small area. For studies of movements, such as gait analysis, force platforms with at least three pedestals and usually four are used to permit forces that migrate across the plate. For example, during walking ground reaction forces start at the heel and finish near the big toe.

Force platforms should be distinguished from pressure measuring systems that, although they too quantify centre of pressure, do not directly measure the applied force vector. Pressure measuring plates are useful for quantifying the pressure patterns under a foot over time but cannot quantify horizontal or shear components of the applied forces. The measurements from a force platform can be either studied in isolation, or combined with other data, such as limb kinematics to understand the principles of locomotion. If an organism makes a standing jump from a force plate, the data from the plate alone is sufficient to calculate acceleration, work, power output, jump angle, and jump distance using basic physics. Simultaneous video measurements of leg joint angles and force plate output can allow the determination of torque, work and power at each joint using a method called inverse dynamics.

Recent developments in technology

Advancements in technology have allowed force platforms to take on a new role within the kinetics field. Traditional laboratory-grade force plates cost (usually in the thousands) has made them very impractical for the everyday clinician. However, Nintendo introduced the Wii Balance Board (WBB) (Nintendo, Kyoto, Japan) in 2007 and changed the structure of what a force plate can be. By 2010, it was found that the WBB is a valid and reliable instrument to measure the weight distribution, when directly compared to the "gold-standard" laboratory-grade force plate, while costing less than \$100. More so, this has been verified in both healthy and clinical populations. This is possible due to the four force transducers found in the corners of the WBB. These studies are conducted using customized software, such as LabVIEW

(National Instruments, Austin, TX, USA) that can be integrated with the board to be able to measure the amount of body sway or the CoP path length during trials for time. The other benefit to having a post-urography system, such as the WBB, is that it is portable so clinicians around the world are able to measure body sway quantitatively, instead of relying on the subjective, clinical balance assessments currently in use.

According to Digital Trends, Nintendo's Wii and the WiiU successor product have both been discontinued as of March 2016. This exemplifies one of the issues arising from the adoption of inexpensive off-the-shelf consumer products re-purposed for medical measurements. Further issues with such adoption arise from the regulatory and standards bodies around the world. Force platforms used for measuring a patient's balance and mobility performance are classified by the U.S. FDA (United States Food and Drug Administration) as Class I Medical Devices. As such they must be manufactured to certain quality standards as established by ISO (International Standards Organization) ISO 9001 Quality Management Principles or ISO 13485 Medical Device Quality Management Systems. Measuring Platforms presents a framework for manufactures and users to verify the performance of Force platforms across the extents of their working surface. Standards such as these are used by manufactures of medical grade force platforms to ensure that measurements made on a patient population are accurate, repeatable and reliable. In short, inexpensive consumer grade entertainment components may be a poor choice for medical measurements given the lack of continuity of such products and their legal, regulatory and perhaps quality unsuitability for such applications

Use in Sport.

Force plates are commonly used in sport to assess an athlete's force producing capabilities. A practitioner can use a force plate to assess training needs, readiness to train, and also during the return to play process. Typical force plate assessments in sport include the countermovement jump (CMJ), squat jump (SJ), drop jump (DJ), countermovement rebound jump, and isometric mid thigh pull (IMTP).

Components of the force plate system

The system has a number of components

- AMTI force plates
- Amplifiers
- A/D Interface Unit (ADIU)
- Event and video control unit (E&VCU) (for use with peak video/optical motion capture system)
- Data acquisition computer with A/D converter card

The force plates

Each plate will produce forces and moments along all three axes, giving a total of 6 channels per plate. The output voltages are fed into two strain gauge amplifiers, one for each plate with their gain set to 2000x.

Amplifiers

Each force plate connects to a six-channel strain gauge amplifier. These have switch selectable gains of 1000x, 2000x, 4000x for each channel. All channels also have a selectable low-pass filter of 10Hz or 1050 HZ cut-off. Bridge excitation levels of 2.5, 5 or 10 volts can be chosen. The output signal is rate up to +10V and is suitable for input into an A/D converter.

A/D converter

The thirty-two channel A/D interface unit receives up to thirty-two analog channels and outputs the signals to a DT-3010 board in the data acquisition (DAQ) computer.

Force Plates Data Acquisition Equipment

A force transducer allows forces exerted on a body to be measured. Although there are many types of transducers, they all work under the same principle – force applied to the transducer causes an electrical signal proportional to the applied force. AMTI

force plates simultaneously measure three force components along the x, y and z axes and three moment components about the x, y and z axes. The forces and moments are measured by foil strain gauges attached to the load cells at the four corners of the platform. The gauges form six Wheatstone bridges having active arms each with eight or more gauges per bridges.

Mechanics of Foot

In a normal living foot that is weight-bearing, as in ordinary standing, passive extension of the big toe at the metatarsal-phalangeal joint will be observed to result in the following effects:

- (i) the arch appears to rise
- (ii) the posterior part of the foot assumes an 'inverted' position (supinates);
- (iii) the leg rotates laterally;
- (iv) there appears a tight band in the region of the plantar aponeurosis.

The short terms 'flexion' and 'extension' are being used for a movement which has previously been shown to be really flexion pronation extension-supination.

A few trials will reveal, however, that as a greater proportion of body weight falls on to the anterior part of the foot the toe extension requires greater force, the extensor muscle becomes inadequate, and the subject experiences an almost painful feeling of tightness in the sole. At this stage he tends to invert his foot voluntarily to relieve this painful sensation. These effects, however, also occur in the dead or the paralysed foot, so it is evident that the action of the invertor muscles of the foot is not necessary.

The four observations listed above also hold in toe-standing, the metatarsal-phalangeal joints in this case being caused to extend by pressure of the toes against the ground.

This is a familiar test in the clinical examination of the foot, the usual, though erroneous, interpretation being that the arch-raising muscles has thereby been proved to be working satisfactorily. When the foot is free, the arch-rising effect is manifested as a movement of the metatarsal head downward relative to the fixed posterior part of the foot. An attempt to oppose this will reveal that-so long as metatarsal-phalangeal extension is achieved-the downward shift of the metatarsal head is irresistible. It is demonstrable in lesser degree in the second, third and fourth rays, a prominence of

them tarsal head in the ball of the foot being the manifestation of its downward shift relative to the rest of the foot.

Arthritis of the Foot and Ankle

Arthritis is inflammation of one or more of your joints. It can cause pain and stiffness in any joint in the body, and is common in the small joints of the foot and ankle.

There are more than 100 forms of arthritis, many of which affect the foot and ankle.

All types can make it difficult to walk and perform activities you enjoy.

Although there is no cure for arthritis, there are many treatment options available to slow the progress of the disease and relieve symptoms. With proper treatment, many people with arthritis are able to manage their pain, remain active, and lead fulfilling lives.

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