

# Gait analysis: past, present, and future

Humankind has always been fascinated by the concept of depicting and recording human motion. During the Renaissance, Giovanni Alfonso Borelli, a student of Galileo, was among the first scientists to analyse motion while developing his theory of muscle action based upon mechanical principles<sup>1</sup>. Early static interpretations of morbid anatomy by Da Vinci and Vesalius were 'brought to life' by the discovery that electricity caused muscle activity, as described by Luigi Galvani in 1791<sup>2</sup>. The first scientific, systematic evaluation of muscle function was conducted by Duchenne who described the function of individual muscles of the human body in a monumental work, *Physiologie des Mouvements*, published in 1867<sup>3</sup>.

Accurate recording of human motion was perfected by Eadward Muybridge, a popular photographer who was asked to photograph a famous racehorse at full gallop. Muybridge devised a race track with vertical markers lined with 12 Scoville cameras, each with electrically controlled shutters triggered by thin threads stretched across the track at 21 inch intervals. The horse's hooves triggered the cameras in order, and a series of photographs clearly depicted its gait sequence. Muybridge subsequently compiled a detailed atlas of human motion, published in 1901<sup>4</sup>.

Meanwhile, in Germany, Braune and Fischer were measuring the motion of human body segments by placing 'Geissler tubes', containing rarefied nitrogen gas, on various limb segments of a human subject dressed in black. Electrical circuits connected to the tubes created incandescence and the illuminated tubes were recorded by cameras as the subject walked in a darkened room. The images were analysed by geometric coordinates from a specially designed microscope. The arithmetic computations describing the motion through space of the trunk and body segments were published in 1891<sup>5</sup>.

Such rudimentary motion recordings were combined with electromyography (EMG) in the mid-1900s in the pioneering work of Innman, Ralston, and Todd in their studies of limb prosthetic research. Their seminal text, *Human Walking*, was published in 1981<sup>6</sup>. Knowledge of pathological gait was expanded by Jacqueline Perry who used electrically activated foot switches along with EMG recordings. A summary of her decades-long research was published in 1992<sup>7</sup>.

Sutherland meticulously measured human gait by recording a child's motion on 16 millimetre film. The images were then individually digitized by hand into a Vanguard motion analyser, a complex and laborious process. This culminated in his publication of *The Development of Mature Walking* in 1988<sup>8</sup>.

Within the last 15 years, gait analysis systems have evolved rapidly. Subjects now simply step on force plates in the floor, while infrared-camera recordings of motions are obtained

from reflective markers placed upon various body segments. This, coupled with either surface or fine wire electrodes, records muscle activity. The subject's motion is recorded on videotape and the measurement data are analysed by computer which provides analytic printouts for evaluation by the kinesiologist and the physician interpreter. Such analysis has led to detailed interpretation of gait in patients with cerebral palsy allowing the surgeon to perform multiple reconstructive surgical procedures involving bone and soft tissue sequentially under one anaesthetic, thereby dramatically reducing the postoperative convalescent period required when such procedures were staged months or even years apart<sup>9</sup>. Furthermore, such operations can be made with greater certainty of outcome.

In the mid-1980s the North American Society of Gait and Clinical Movement Analysis (GMCA) was formed, one of its goals being to develop standardization of testing techniques. The GMCA now has more than 280 members. Concurrently, a European Society for Movement Analysis has formed and much interchange is now provided.

Nowadays the clinician has readily available technology to analyse human motion. Although most research has been devoted to the child with cerebral palsy, more attention is now being directed to paralytic conditions and to testing improved orthotic and prosthetic designs. The future holds promise for further refinement; computer technology may soon provide CD-ROM format reports with interpretation which is more user-friendly for those physicians unaccustomed to current analytical graphic analyses.

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