



# Video Gait Analysis in the Podiatric Sports Medicine Clinic

Technological advances have improved this valuable tool.

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**G**ait analysis involves much more than simply watching someone walk or run. Forms of gait analysis include: plantar pressure measurements, muscle EMG, 3-D computer-aided analysis, energy cost as measured by oxygen ventilation, power output, and center of mass deviations. Each of the methods of gait analysis provides specific forms of information, but none of them can paint a complete picture of the complexities of human gait. This article will focus on 2-dimensional video gait analysis, primarily because it is relatively inexpensive and can be incorporated into a podiatric clinical setting easily.

## Observational Gait Analysis

Observational gait analysis has been practiced for more than 100 years but became more of a science in the 1970's when pressure mat technology and high-speed video became available. Mechanical analysis and mathematical modeling of gait have become increasingly sophisticated as the technology utilizing force platforms, high speed video, accelerometers, and more powerful computers continues to advance.<sup>10,11</sup> While video gait analysis has not caused a revolution in the clinical setting, it has provided the opportunity in research settings for a better understanding of human movement, and is becoming a more useful clinical modality for sports medicine practitioners.

Biomechanics and human performance research labs began using video gait analysis (VGA) techniques en masse in the 1970's and 1980's as the technology became more user-friendly and affordable. As technology improved and the body of knowledge grew, some clinical settings adapted the techniques to better evaluate movement pathologies, to provide a visual record of therapeutic progress, and to assist in surgical planning for neuromuscular disorders such as cerebral palsy. Early research often focused on attempts to understand normal gait, gait development in children, and deterioration of gait in the elderly.<sup>11</sup>

In the athletics setting, VGA has been used by coaches and trainers to evaluate and refine sport-specific skills, and thereby improve performance and/or decrease risk of injury. Recently, there has been growing acceptance of the use of VGA in the clinical sports medicine and rehabilitation setting.<sup>1,18</sup> Physical medicine and rehabilitation practitioners have increasingly used VGA to assist in evaluation and therapy of gait pathologies related to traumatic brain injuries. Physical therapists are increasingly employing VGA into their practices as well. Many running footwear retailers, despite lacking formal biomechanics training, are now using it to sell running shoes.

Sports medicine podiatrists, while not always providing rehabilitation services in the clinic, are typically prescribing and monitoring the rehabilitation of their patients. Video gait analysis can serve as an additional clinical tool to better visualize biomechanics and movement patterns in order to monitor treatment progress. It also provides visual information to improve communication with patients. Gait analysis has been increasingly used to evaluate a subject's movement patterns in order to assist in diagnosing pathologies, improving performance, and/or monitoring therapeutic interventions such as gait retraining or orthoses.

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The primary criticism of observational gait analysis (OGA) is the limited reproducibility and usefulness of the data and/or subjective observations. Newer video analysis software has overcome some of these limitations. Much of the published research supporting use of video analysis is on pathologic gait such as in cerebral palsy or traumatic brain injury. Most research on the reliability and repeatability of OGA as well as other orthopedic measures points to low to good inter-rater reliability, and often better variability with more experienced observers.<sup>3-4,6-9,22-23</sup> Some studies have shown good reliability in rehabilitation settings with hemiplegic patients.<sup>8</sup> Some of the studies evaluating gait analysis reliability were done without the capability of slowing down or stopping the video for a more detailed exam, which likely contributes to less than optimal outcomes. Newer high-speed video analysis software allows observers to slow down (even frame-by-frame), magnify, and stop the video. They also include tools for calculating angles and obtaining other measurements. A recent study using software with this capability (Dartfish®) showed that inter-rater reliability was higher with the software with tools versus using standard video software that lacked these tools.<sup>25</sup>

### Physician Rating Scale (PRS)

In an attempt to standardize Observational Gait Analy-

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sis (OGA), some researchers advocate using summary assessments such as the Physician Rating Scale (PRS).<sup>5</sup> The PRS classifies six gait variables on a 2–4 point scale. When tested on the PRS, some variables, such as knee position in mid-stance, have been shown to have good to excellent reliability yet only moderate accuracy. The research does seem to suggest that the more variables that are observed, the less accurate are the observations; so, it may be likely that future studies will show better reliability and repeatability with more specific observational criteria. Formal methods of OGA such as the Rivermead Visual Gait Assessment or the Observational Gait Scale appear to improve the reliability of judgments, yet they do not necessarily affect the accuracy.<sup>7</sup> Gait researchers seem to agree that standardized gait analysis training and methodology would likely improve outcomes.<sup>1,9-11</sup>

While the body of research on human movement has grown tremendously in the last 30 years, there is still no single universally agreed-upon model of normal human gait. Human movement patterns are highly unique and are affected by a large number of variables including age, sex, and body composition. Even mood and culture influence how humans ambulate. To complicate matters further, humans do not respond in systematic ways to orthotics, bracing, footwear, or other biomechanical interventions.<sup>15</sup>

It seems obvious, but in order to assess abnormal gait, it is imperative to understand normal gait.<sup>2</sup> One study concluded that a key reason for low reliability was that the raters did not seem to be familiar with the normative values for the tested gait variables.<sup>9</sup> Not only is a grasp of normal gait important but also understanding common gait compensations is essential.<sup>10</sup> Biomechanics and gait theories arise from different corners of the research field. The disciplines of podiatry, physical therapy, orthotics/prosthetics, exercise physiology, and neuroscience, among others, have unique and oftentimes conflicting theoretical perspectives on human movement. Practitioners should make an effort to understand the different theoretical principles.<sup>10</sup>

Humans move in the manner that is most metabolically efficient and causes the least amount of discomfort.<sup>19</sup> The metabolic energy cost of walking and running is due to the acceleration and deceleration of the body on each step. Conserving energy of ambulation is achieved by minimizing the vertical and lateral displacement of the human's center of mass (CoM). The CoM is located just anterior to the second sacral vertebra and midway between the hip joints. It is impossible to ambulate without vertical and lateral translations of CoM.<sup>1</sup>

Saunders and colleagues in 1953 used the term “determinants of gait” to describe key gait strategies humans use in order to control the CoM and minimize the metabolic cost of gait. Other researchers have now refined Saunders' original five determinants to six.<sup>11,16-17</sup> While there is general agreement by researchers that these movements occur, there remains controversy on their role in energy conservation. Understanding these determinants of gait are an important part of mastering the fundamentals of gait.

**1) Pelvic rotation:** The pelvis rotates in the transverse

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plane to bring the hip joint forward during hip flexion and backwards during hip extension. The hip rises and falls vertically during this movement. Pelvic rotation allows the hip joint to move through a smaller distance than the foot for a given stride length. This conservation of hip ROM is more efficient than a hip that is fixed in the transverse plane, and results in decreased vertical movement of the hip, further conserving energy and providing a smoother movement pattern.<sup>1,11</sup>

**2) Pelvic obliquity:** The pelvis tilts in the frontal plane in an alternating manner with hip flexion and extension so that when the hip of the stance leg is at its highest point, the pelvis slopes downward so that the hip of the swing phase leg is lower. This pelvic tilt conserves energy by minimizing vertical displacement of the trunk. During normal walking gait, the pelvis drops 4-5 degrees from the stance leg to the swing leg.<sup>1</sup> This determinant presupposes that

the swing leg can be shortened adequately to clear the ground through knee flexion and ankle dorsiflexion.

**3) Knee flexion in stance phase:** Knee flexion in mid-stance shortens the leg, which minimizes vertical displacement of the CoM. Peak knee flexion is approximately 15 degrees in normal walking.<sup>1</sup>

tial contact, the foot lengthens the leg at toe-off as the ankle plantarflexes—again, minimizing vertical displacement of the CoM.

**6) Lateral displacement of body:** A narrow base of gait requires less lateral movement in order to preserve balance. Energy is conserved by minimizing lateral movement of the CoM.

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**4) Ankle mechanism:** The heel effectively lengthens the leg at initial contact because it is located posterior to the ankle joint. This minimizes vertical displacement of the CoM.

**5) Foot mechanism:** Just as the heel effectively lengthens the leg at ini-

Gait abnormalities can be placed in perspective by keeping the above six concepts in mind. Deviations from the above parameters should raise questions or at least attract the observer's attention. Because humans place such

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a high priority on moving efficiently, they only deviate from these patterns to avoid painful stimuli, or because they cannot move in the most efficient manner because one or more segments of the kinetic chain are dysfunctional. This dysfunction could be due to hyper- or hypo-mobility of joints, muscle imbalances, vestibulomotor problems, or sensory deficits.

Gait analysis is easily performed in the clinical setting and incorporates patient history, physical exam, and functional assessment.<sup>1</sup> VGA can be done using a single high-speed, high-definition camera, video software, and a treadmill. A systematic approach to gait analysis is important since the gait cycle is so short and repetitious.

A typical gait analysis protocol starts with a general assessment and becomes more focused. Initial assessment looks for symmetry and smoothness of movement. Next, temporal-spatial parameters such as cadence in steps per

minute, angle and base of gait, stride length, arm swing, movement of the trunk, and rise of the body are assessed and measured.<sup>1,10-11</sup> Although measuring speed, cadence and stride length is easily done, many researchers question the value of these measurements since there is such a broad range of what is considered normal.

For example, intrinsic factors such as subject height, sex, and extrinsic factors such as length of runway, treadmill, or even room size affect temporal gait parameters.<sup>9,13-14</sup>

Finally, kinematics are assessed by observing subjects' gait from lateral, anterior and posterior views to assess sagittal and frontal plane movement. Some labs use ceiling-mounted cameras directly over the subject to capture transverse plane motion. Key kinematic angles and events as described by Kirtley<sup>10</sup> are:

- Ankle dorsiflexion at contact
- Maximum rearfoot eversion
- Knee flexion at contact

- Knee adduction in late stance
- Ankle plantarflexion during push-off
- Knee flexion in swing

#### **Visual Feedback to Patients**

A significant benefit of VGA is the visual feedback it provides to patients. By being able to see their gait patterns, they are better able to understand the problem and the objective of therapeutic interventions. Patients often expect to see dramatic kinematic differences in different shoe and/or orthotic conditions. However, kinematic alterations (such as peak rear-foot eversion) due to orthotic interventions in runners, while they can be significant, are often smaller than expected.<sup>15</sup> Kirby and others have proposed that the positive benefits of orthoses are likely due to mechanisms other than alignment or kinematic changes.<sup>12</sup>

A significant limiting factor evident with VGA is that the motion of the foot

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# CURRENT TOPICS IN SPORTS PODIATRY

## VIDEO GAIT ANALYSIS

is disguised when shod (Figures 1 & 2). Researchers have used running sandals and cut holes in heel counters to overcome this limitation, however, this is not practical in the clinical setting. Stacoff's study showed that shoes actually exaggerate the appearance of rear-foot frontal plane motion.<sup>20</sup> Awareness of this limitation is important to keep in mind when evaluating kinematics of gait.

Does the video replace or supersede a physical exam? Certainly not, but it can shed light on gait impairments that may not be revealed in a static assessment. According to noted gait researcher Casey Kerrigan M.D., "...gait analysis can be used to focus and optimize rehabilitation treatment including prescription of exercises, biofeedback... (or) orthotics..."<sup>1</sup> According to author and researcher Michale Whittle, "With the improvements in measurement and analytical techniques, the major limitation now is not the ability to produce high-quality data but knowing how best to use these data for the benefits of patients."<sup>15</sup>

Mathematical and robotic modeling of the musculoskeletal system holds promise for the future of gait analysis and therapy. Computer programs will one day allow us to input patient data from a gait analysis, and then create models to see how that model responds to interventions.<sup>1,10-11</sup> **PM**

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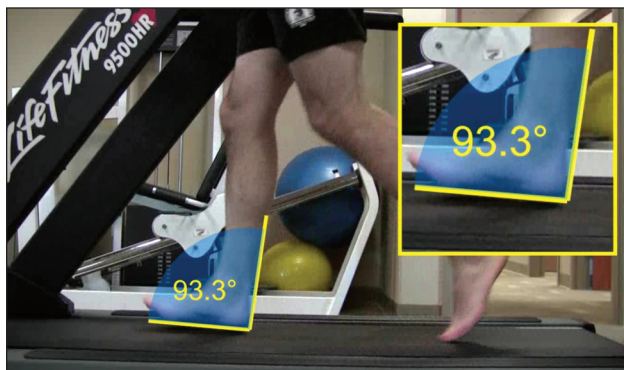


Figure 1: Runner with decreased ankle dorsiflexion and mid-foot landing pattern at initial contact as is common in barefoot running gait



Figure 2: Same runner as in figure one with increased dorsiflexion and heel strike landing pattern as is common in shod running gait.

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