CURRENT CHALLENGES IN CLINICAL GAIT ANALYSIS

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Video based systems for analyzing human movement began evolving in the early 1970s. By the mid 1980s, commercial systems had grown out of these early efforts. Basic, standard arrangements of reflective markers placed on the lower limbs and associated methods to compute joint angles from these markers were also developed. These marker sets were created to work with a small number of cameras (3 or 4) which by today's standards had exceedingly poor resolution. Capturing and reconstruction software was rudimentary, meaning that sometimes hours were needed to process a single trial. Thus, simplicity and a minimum number of markers were the imperative of the day. Today's gait laboratories typically have at least twice the number of cameras (8-12) that were the standard in the 1980s and 1990s. More importantly, each of these cameras has many times the resolution of their predecessors. The capturing and reconstruction software have advanced to the point where it is now possible to process data in real time. Modern systems are therefore easily capable of tracking many times the number of markers which limited the early model development. Yet with all these advances, most labs use the same commercial gait models that were developed for the earliest technology. Some of the specific clinical deficiencies of these gait models are:

Joint axis identification. There are various options for the user to attempt to align markers that reflect the axis about which knee and ankle motions occur. Attempting to specify these axes using surface markers is notoriously unreliable. This leads to a reduction in reported flexion and erroneous increases in other angles. Misalignment of the knee axis also directly affects hip rotation angles. Accurate representation of this parameter would be greatly beneficial in eliciting the effects of femoral anteversion. Errors of 10 to 15° are not uncommon, and these are of the same magnitude as pathologic values of anteversion, so this measure is not normally helpful.

Hip joint center location. In order to accurately compute hip kinematics and kinetics, the location of the femoral head must be known. Unlike the knee and ankle, the hip joint is not easily accessed. To locate hip joint centers, markers are placed on the pelvis, and the hip joint is determined using a calculation with parameters determined from normal individuals. Some or many of the patients seen for gait analysis may not fit this normal profile, particularly those with hip dysplasia. For these individuals, there are likely gross inaccuracies in hip joint kinematics and kinetics.

Skin motion. An inherent problem with any surface marker model is motion of the skin relative to the bone. The biomechanics of interest are those of the bony segments. As joints move and muscles change shape, the skin surface will translate relative to the underlying bone. Marker landmarks are chosen to avoid particularly muscular regions, but there will always be some error. In current models there is no way to assess or compensate for these inaccuracies.

Foot model. One of the greatest frustrations with current models is the lack of useful information about the foot. Many multisegmental foot models have been developed and validated, yet commercial gait models treat the foot as a single rigid segment, essentially a "foot bone" and motions within the foot are attributed to the ankle joint. This approach to foot modeling is a direct result of limitations of older systems.

Interlaboratory consistency. A recent study[1] showed that while systems in different labs produced reliable and accurate data, there were large differences between labs due to marker placement (*e.g.* hip rotations varied by as much as 28°). This study highlights some of the sensitivities and difficulties of marker placement in current models.

Additional segments. During gait the trunk is often used to compensate for distal motor deficiencies. While trunk and upper extremity models are now commercially available, standardization on their implementation is lacking. Because these were only recently developed commercially, many users had already created their own models. Thus there is little agreement on marker placement and computational methods for the trunk, head and upper extremities.

Additional quantitative parameters. Current commercial software computes joint angles, temporal parameters and, if force plate data are present, joint moments and powers. There are other parameters however which may be useful in assessing a patient's current status or outcome. These include the "gait index" and functional muscle lengths. While these data may be processed with the information from current models, additional software and processing steps are required.

Muscle Forces. While EMG provides valuable information about muscle timing, there is no way to predict muscle forces with standard software. Information about individual muscle forces could be invaluable to treatment planning. This analysis requires muscle modeling and optimization techniques and may represent the next generation of gait software.

In summary, while current commercial gait models have been providing useful clinical data for many years, there are several recognized inherent deficiencies. New cameras allow for many more markers to be visualized and real time tracking technologies could be employed to develop more sophisticated data collection methods which may address these limitations. Recent commercial programs have made strides toward some of these issues, but most laboratories have yet to adopt these.

1. Gorton et al. *Gait and Posture* 16(S1):S65-6, 2002