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The evolution of clinical gait analysis part III – kinetics and energy assessment

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Abstract

Historically, clinical applications of measurements of force and energy followed electromyography and kinematics in temporal sequence. This sequence is mirrored by the order of topics included in this trilogy on the *Evolution of Clinical Gait Analysis,* with part I [Sutherland DH. The evolution of clinical gait analysis part I: kinesiological EMG. Gait Posture 2001;14:61–70.] devoted to Kinesiological EMG and part II [Sutherland DH. The evolution of clinical gait analysis part II – kinematics. Gait Posture 2002;16(2):159–179.] to Kinematics. This final review in the series will focus on kinetics as it relates to gait applications. Kinematic measurements give the movements of the body segments, which can be compared with normal controls to identify pathological gait patterns, but they do not deal with the forces controlling the movements. As a major goal of scientifically minded clinicians is to understand the biomechanical forces producing movements, the objective measurement of ground reaction forces is essential. The force plate (platform) is now an indispensable tool in a state-of-the-art motion analysis laboratory. Nonetheless, it is not a stand-alone instrument as both kinematic and EMG measurements are needed for maximum clinical implementation and interpretation of force plate measurements. The subject of energy assessment is also given mention, as there is a compelling interest in whether walking has been made easier with intervention. The goals of this manuscript are to provide a historical background, recognize some of the important contributors, and describe the current multiple uses of the force plate in gait analysis. The widespread use of force plates for postural analyses is an important and more recent application of this technology, but this review will be restricted to measurements of gait rather than balance activities.

Finally, this manuscript presents my personal perspective and discusses the developments and contributors that have shaped my thoughts and actions, and which I have found to be particularly noteworthy or intriguing. Just as in parts I and II, emphasis has been placed on the early development. All subtopics and important contributors, in this third and certainly most challenging of the review papers, have not been included. Some may find that my perceptions are incomplete. I accept responsibility for all deficiencies, as none were intended. Letters to selected contributors and their responses reveal how each contributor built on the work of others. The level of cooperation and sharing by these early investigators is extraordinary. Had they wished to withhold information about their own work, clinical gait analysis would have been severely delayed.

Keywords: History; Kinetics; Energy cost; Clinical gait analysis

1. Introduction

The force that the human subject applies to the ground or floor is equally matched by the reaction of the floor or ground. Even primitive man made deductions about the activities of animals or humans from their paw or foot prints. Without any knowledge of Newton's formulae for the effects of gravity and the third law of motion that states, ''for every force applied there is an equal and opposite reaction'' [3], they understood that bodies have mass (weight), and could deduce much about the identity of animals or humans from the shape, depth, alignment and spacing of the prints they produced.

The search for scientific methods of recording the magnitude of foot/heel contact began in the 19th century. Carlet, of France [4,5], and Ampar, his student, developed and utilized air reservoirs to measure the force applied to the heel and forefoot. Carlet started this work as a student of Marey, at his laboratory in Paris. A significant limitation of

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children stopped walking in their 20's and 30's was due to weight gain and declining maximal aerobic capacity.''

''Myelodysplastic children, due to their light total body weight, strong arms and relatively high maximal aerobic capacity, were able to functional ambulate even with much greater paralysis than adults with spinal cord injury. Many had a very functional swing-through gait and were able to meet this energy demand. However, as in cerebral palsy, with advancing years, we concluded this high rate of energy consumption became no longer tenable so that those children with severe lower limb paralysis generally became wheelchair users.''

''I do not believe it necessary to routinely perform energy consumption studies in all patients. As in any clinical measurement, there are specific indications for ordering a test. However, energy consumption provides important information any time walking endurance or fatigue is of clinical concern. Energy consumption studies enable one to advise patients on the practical scope and range of walking activities. From an energy conservation perspective, this information helps the clinician recommend to the patient daily living walking activities in such a way as to keep energy demands within a reasonable limit. Energy consumption can provide information when walking is no longer practical and when wheeling is preferable.'' [88–90]

Appendix C. Quote: Jessica Rose, PT, Ph.D.

''I became interested in gait analysis as an undergraduate student at UC Davis while working with children with cerebral palsy as a volunteer at a Medical Therapy Unit in Sacramento. Dr. Warden Waring, a biomechanical engineering professor at Davis gave intriguing lectures on center of pressure movement during gait; thus, I became aware of the impact of gait deviations on center of pressure displacement and the energy cost of walking. Unfortunately, my sister had suffered a severe head injury after being hit by a drunk driver and was struggling to recover. She had and still does have difficulty walking and I became keenly aware of how fatiguing walking disorders can be and the importance of the energetics of walking.''

''While in physical therapy school at Stanford, my mentor, Dr. Ann Hallum (now at SF State, she used to direct the PT school there and now is a Dean) suggested that I contact Dr. Henry J. Ralston, a physiology professor at UCSF who was an expert on the energetics of walking. He became an important mentor and helped me to apply his expertise to cerebral palsy gait analysis.''

''It was at my own initiative to study heart rate while walking in children with cerebral palsy, it seemed to be a simple and inexpensive estimate of energy expenditure. The complications with heart rate are primarily related to resting heart rate, which as you know, decreases with age and increases with anxiety. A good study would be to determine if walking heart rate or walking heart rate – resting heart rate is most highly correlated with oxygen consumption/kg while walking. We have assumed it would be better to subtract the resting rate, but I'm not sure if that has ever been determined.''

''We do routinely measure resting and walking heart rate and record the slow, comfortable and fast walking speeds and energy expenditure index (EEI). We do not call it the physiologic cost index (PCI) because Dr. Ralston insisted on being specific and pointed out that there is more to physiologic cost than energy expenditure, and that what was being estimated was energy expenditure, and thus, we still refer to it as EEI.''

''As the methods of direct measurement of energy expenditure improve and become less cumbersome and expensive, I do believe that heart rate monitoring will be less common and, given the choice, I would prefer to have oxygen consumption data. Unfortunately, my capital budget has not allowed this yet, but it is a goal!''

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