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The evolution of clinical gait analysis part l: kinesiological EMG

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Abstract

In 1996, I was asked by Roy Davis, President of the Gait and Clinical Movement Analysis Society, to be the presidential guest speaker at the Birmingham, AL, annual society meeting and present a talk on the development of clinical gait analysis. Following my presentation, James Gage, Editor-in-Chief for Gait and Posture, and David Winter, Associate Editor for review articles requested a manuscript for publication. To address this task I have the advantage of being a participant throughout this exciting era and of personally knowing most of the people mentioned in this manuscript. To prepare for this assignment, I wrote letters and/or made phone calls to them. Their replies to my inquiries, plus their publications, provide documentation for this review paper. The opinions expressed, for better or worse, are my own. Due to space limitations, only a partial list of the many that have contributed is presented and I regret that not all of the important contributors have been included. In some instances they will be found in Part II and Part III. Hopefully, later publications on this subject will correct the omissions. Emphasis has been given to the earliest years and to walking gait. The subject of upper extremity analysis has not been included, though studies of subjects with upper extremity motion problems are carried out in many motion laboratories including our own. A further disclaimer is that the flood of more recent publications does not receive equal coverage. History is being written daily as clinical gait analysis gains momentum. We have barely scratched the surface of the development and potential contributions of clinical gait analysis.

Keywords: History; Electromyography (EMG); Clinical gait analysis

1. Introduction

The origins of the science of gait analysis began in Europe in the 17th century and continued through the early 20th century. The discoveries of such notables as Borelli [1], Galvani [2], Newton [3], Descartes [4], Marey [5–7], Carlet [8], the Weber brothers [9,10], Scherb [11–13], Duchenne [14], Muybridge [15], and Braune and Fischer [16–20] provided a solid scientific foundation for our current understanding of human walking. Braun and Fischer employed the principles of Newtonian classical mechanics, the coordinate geometry of Descartes, and Borelli's mathematical concepts for estimating muscle action, to create an elegant representation of the gait of their military subjects carrying backpacks. Although the principles of investigation employed by Braun and Fischer are recognized as valid today, their methods of study were far too labor intensive to permit any practical application for subjects in a clinical setting.

Vern Inman, and colleagues moved the science of gait analysis dramatically forward by adding kinesiological electromyography (KEMG), 3-D force, and energy measurements in the study of walking in normal subjects and amputees (1944–1947). The remarkable contributions of this inspired team, led by Inman, are contained in a report to the National Research Council [21] and are printed in a limited number of publications [22–24]. Nonetheless, their methods of study were still too labor intensive, invasive, and computationally demanding to permit their application in a clinical setting. Colleagues of Dr Inman published Human Walking [23] in the year following his death. Now in its second edition [25], this book contains a distillation of much of the original work of the team, as well as many new contributions by contemporary researchers. It receives wide recognition as an outstanding presentation of the scientific basis for gait analysis.

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from the Pathokinesiology Laboratory at Rancho Los Amigos Hospital, John Medeiros and Neil Adler from Packard Stanford Children's Hospital Gait Laboratory and Marilynn Wyatt from San Diego Children's Hospital Motion Analysis Laboratory. The proctors for the examination were physical therapists Arnold Tripp, Helen Hislop and an orthopedic surgeon, Jacquelin Perry. The examination was both written and practical. The subjects for the practical portion were physical therapy students. At the present time, there are approximately 86 physical therapists licensed in California to perform fine-wire kinesiologic EMG. Those that are active today largely limit their practice to clinical gait laboratories. Training for fine-wire insertions has been carried out at Rancho Los Amigos Hospital Pathokinesiology Laboratory. Also, beginning in 1989, a yearly instructional course, with hands-on experience, has been offered at San Diego Children's Hospital Motion Analysis Laboratory.

6. Future

Most investigators understand that muscle action potentials (EMG) represent the muscle activation signal, not the resulting muscle tension. Although there is a linear relationship between EMG and muscle tension, this is only true when the muscle is acting isometrically. Muscle length, load, and angular velocity are changing frequently during gait, so it is fair to say that no linear relationship between EMG and muscle tension can be assumed [56]. Are there other measurement tools that may be capable of expanding our knowledge of individual muscle function? The buckle tendon transducer, widely used in animal experiments, is a wonderful tool to directly measure tension in a tendon. Unfortunately, in its present form, it is too invasive to be considered for use in clinical gait analysis.

The most promising measurement tool under current investigation is the intramuscular pressure probe. The activation signal (EMG) begins before, and ends a short time before the drop in, muscle tension. Furthermore, KEMG gives no direct information about the contribution of passive stretch to muscle tension [57]. There is experimental evidence to show that dynamic intramuscular pressure records both active and passive components of muscle action [58–60]. There are ongoing efforts to develop an intramuscular pressure sensor that is small enough to be inserted through a fine gauge needle. Experimental studies will be required to establish the relationships between IM pressure, muscle tension, and EMG. If current research in the laboratory of Dr Lieber confirms a linear relationship between IM pressure and muscle tension, a powerful new tool will become available for both motor control research and clinical studies [61]. A possible scenario is that pressure changes may precede EMG in some lower extremity load-bearing muscles, indicating that muscle stretching is occurring before muscle activation.

We may have reached a relative plateau regarding technical applications of EMG, but our understanding of muscle physiology, functional biomechanics and the human control system must expand to keep up with technical progress. The application of the best methods of study and interpretation of the data, both for individual patients and patient populations, can further improve the quality of life for patients with neuromuscular diseases [62]. Collaborative, multicenter, prospective studies, maintenance of data banks and rapid communication of results will speed the transfer of knowledge to aid patients (Figs. 1–8).

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