Chapter

Introductory Chapter: Biomechanics, Concepts and Knowledge

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1. The concepts and basis of biomechanics

The achievement of the human voluntary movement is seemingly simple, but rather it is considerably complex. As it is a very complex mechanism which allows many nerve structures to make decisional and/or reflexional choices, then this mechanism "defines" and "controls" the movement, through the nerve impulses intended for the musculoskeletal system. In the human body, around 640 muscles are involved with 213 bones rigidifying several segments ranging from a few cm^3 to several thousand cm^3 through more than 100 joints. The whole system thus allows greater than 100 degrees of freedom. Biomechanics study the complexity of the human body through behavior and performance in daily life with respect to musculoskeletal system with the aim to optimize the system [1, 2]. This discipline seems essential in today's world and considerably promising for the future. Indeed, the concepts, methods, and analytical techniques that we use to characterize human mechanics represent major economic stakes. The development is necessarily inscribed in a vision of interactions between the physical sciences (metrology, complex mechanical and electronic systems), information sciences and technologies, and life sciences (materials, tissues, organs, and limbs) [3–8]. The ambition of the research work carried out in biomechanics is to improve the performance of high-level athletes and the comfort and quality of life of patients and to minimize stress on joints in real-field or laboratory situations. Biomechanics is subdivided into kinematic (**Figure 1**) and kinetic (**Figure 2**) analyses. Kinematics is concerned with the analysis of motion (e.g., to determine the forces applied to a joint from the inverse dynamics), while kinetics studies the forces that cause or result from it (e.g., the reaction of the ground when walking).

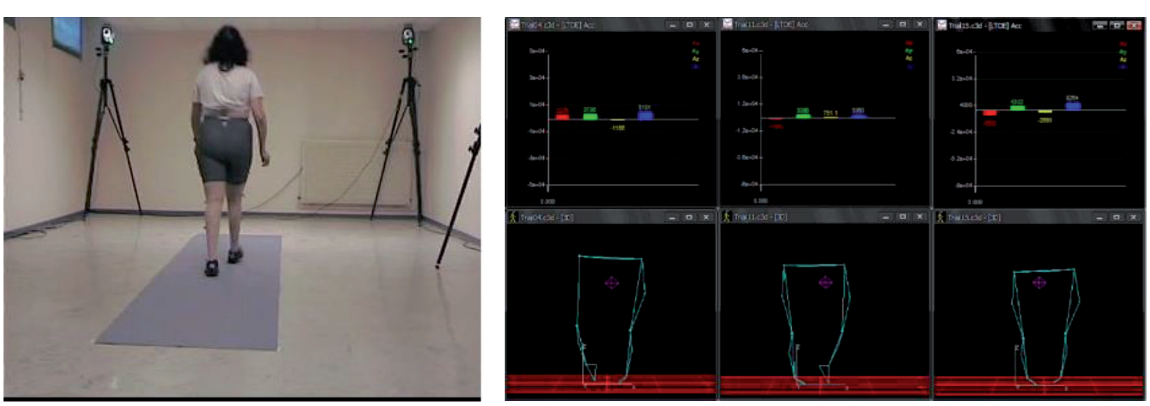

Figure 1.
Kinematic device for 3D motion analysis. The example of a patient with myopathy.

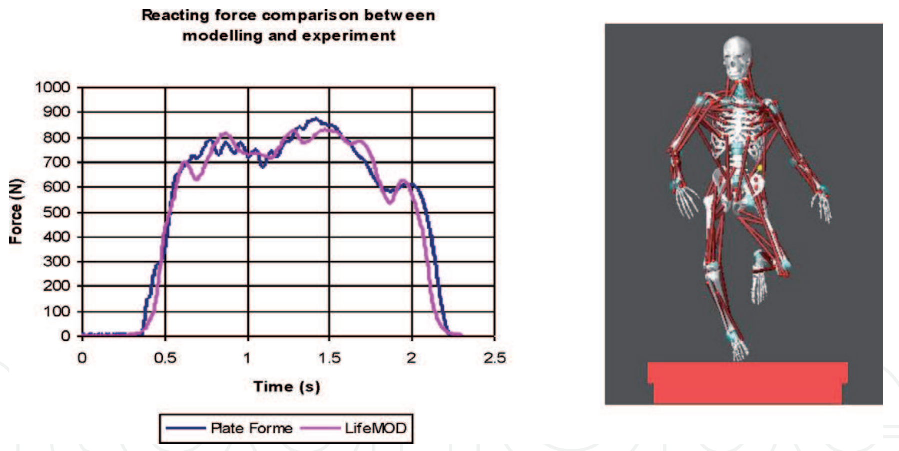

Figure 2.
Kinetic analysis of motion. Correlation between modeled and experimental data.

2. Modelization in biomechanics

Different models can be considered ranging from the human body represented by its center of gravity to the model integrating both motor control and musculoskeletal modeling of the human body. With the current medical techniques (Scanner, MRI, and X-ray) and recent computer modeling, many technical and scientific advances are now possible in biomechanics [9]. The aim is to modelize mathematically (**Figure 3**) and simulate the mechanical behavior of the human body under the application of various constraints. This model will be correlated with cases of declared pathologies by considering behavioural control as a main objective of prevention (**Figure 4**). The simulation will make it possible to predict the appearance of pathologies that may slow down the stability or progression of human mechanics in all combined fields [10–12]. The recommendations will be applicable with the aim to optimize human mechanics.

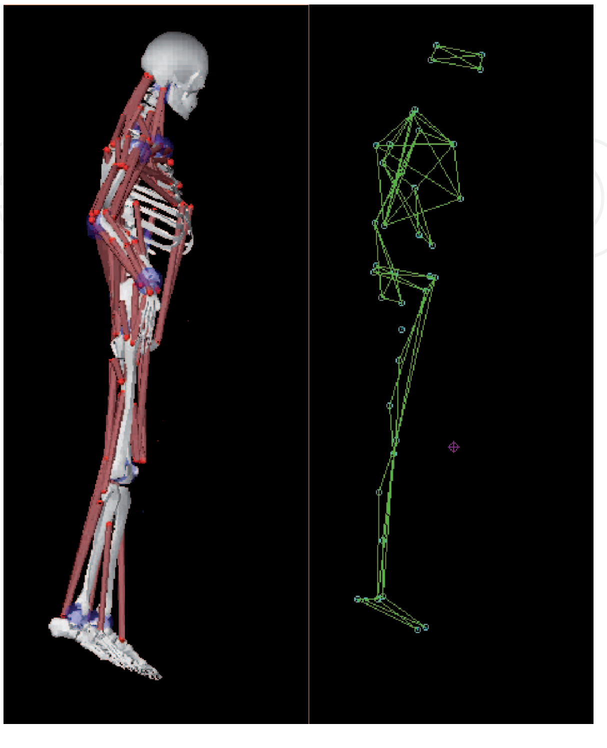

Figure 3.
Dynamic modeling from kinematic data, example of a vertical jump.

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Figure 4.
Dynamical simulation permitting the optimization of the movement.

Mathematical modeling in life sciences or medical sciences is hardly developed. This modeling involves applying physical laws to analyze both human and animal movements and to quantify and analyze the discriminating parameters of movement. Given its very complex approach, "skeletal" modeling consists of representing the body by a certain number of segments (often considered indeformable to simplify calculations). The interest of this modelling lies in the possibility of combining and coordinating research results [9] with an efficient way in innovative projects oriented towards CAD—simulation—rapid prototyping (**Figure 5**). Applications will be in medicine (e.g., development of new orthotics) and in sports (e.g., proposing a methodology for optimizing sports clothing).

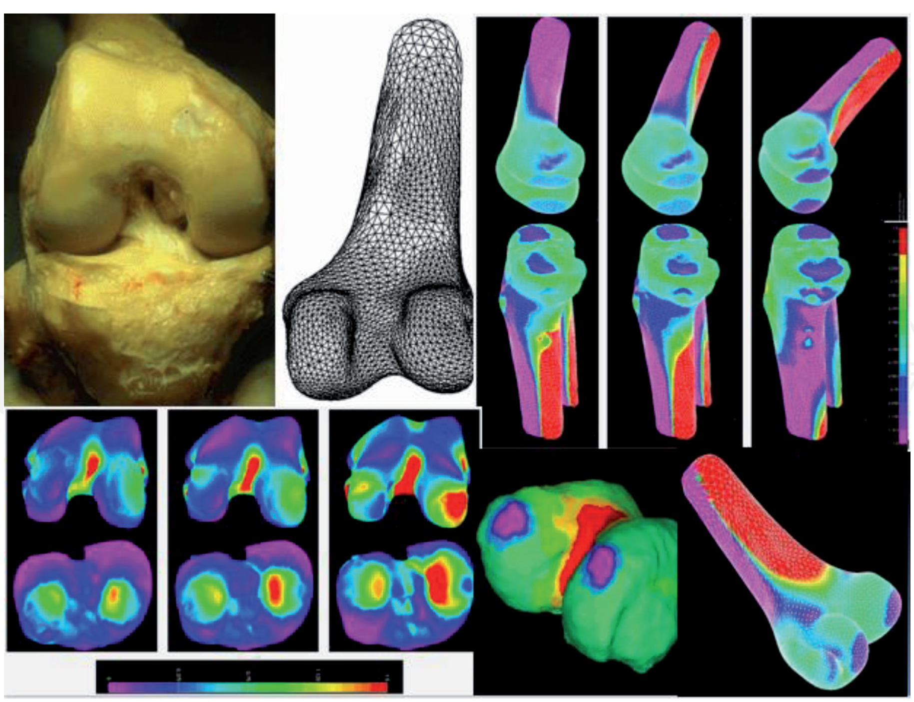

Figure 5.
Anatomy (image formation), CAD, mesh, and finite element analysis of the knee joint. Procedure and quantification of mechanical stress at the joint level.

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