ABSTRACT

This review is aimed to revise the essential role of biomechanics in musculoskeletal rehabilitation and it also try to illustrate the application of biomechanics in neurological rehabilitation. In addition it clarifies the application of biomechanics for evaluation and training normal walking and running gait. By using different biomechanical sensors, accurate mathematical applications, biomechanical applications are very necessary for neural and musculoskeletal rehabilitation as well as normal or impaired gait/walk. Analysis in clinical assessment of injuries and the design of joint replacements for degenerated joints, one of the most mature applications of computational biomechanics are indicated in this review paper. Assessment of kinematic modeling developed for two to four sensors that can monitor the rehabilitation of patients with neurological disorders are seen. Replacing degenerated joints, detecting stress in bones, stress in inter vertebral discs, chest well deformations, force induced by tendons and ligaments, angles between body segments during gait are some of the biomechanical applications were seen as the necessary applications in rehabilitation science. Finally this integrated biomechanical computation creates positive impact on orthopedic education, basic research, device development generally and clinical patient care related to musculoskeletal joint system reconstruction, trauma management, and rehabilitation as well are the most valuable applications of biomechanics.

Keywords: Biomechanics; Gait; Masculoskeletal; Neurological; Rehabilitation

INTRODUCTION

Human locomotion has been studied, since the time of ancient Greece. Locomotion is a complex and rapid activity and therefore, difficult to record visually. As a result, locomotion studies have been heavily dependent on the available technology. The scientific observation of human locomotion originated in the 19th century, with the introduction of the photographic camera. After the application of force plate technology motion data could be gathered to give a full kinematic and kinetic analysis of gait. This basic technology has improved to include television based camera technology, inexpensive 3D force plates, latterly video cameras have come to existence (Philip R., 2012).

In recent years, the expansion of science and technology, creating an overlap between the biological sciences and engineering know-how has made the possibility of Virtual Human as a reality rather than a visionary concept (Chao et al., 2007). This paper introduces the development and applications of biomechanics for human musculoskeletal and neurological rehabilitation, which will
enable the execution of a wide spectrum of biomechanical analyses under simulated or experimentally measured functional environment. The basic and applied disciplines influencing orthopedics and rehabilitation have experienced tremendous growth since their inception and this has resulted in improved clinical care. Researches on dissected cadavers and experiment animals can describe how bones, muscles, and tendons connect in a complicated geometry; how muscles exert forces on joints; and even how impulse in the brain can trigger a muscle's contraction. In the meantime, clinicians have been treating people for sports injuries, stroke, and movement diseases such as cerebral palsy and osteoarthritis. Using trial and error, they were assessed which rehabilitative strategies and surgical interventions work best. Clinical observations might miss the interplay of forces that lead to an injured knee, while static equations regarding the flexion of a dead man's knee may have a little help in treating a torn ligament. Researchers were missing the cause-and-effect models that linked the physical forces with the clinical outcomes. Now, computational models are filling the gap between brain signals and gross Human movement. Recently, researchers and clinicians are trying to bring biomechanics application knowledge from the grass root level (Regna N, 2007).

OBJECTIVE

The main aim of this review is

1. To revise the essential role of biomechanics in musculoskeletal rehabilitation.
2. To illustrate the application of biomechanics in neurological rehabilitation.
3. To clarify the application of biomechanics for evaluation and training normal walking and running gait

Biomechanics in Rehabilitation

Over the past quarter century, extensive research has been done on musculoskeletal biomechanics. As the number of older adults rapidly increases, so has concern about how to manage conditions endemic to this population such as osteoarthritis of the hip and knee. For younger active adults areas garnering considerable research focus have included management of patella femoral disorders as well as prevention or subsequent repair of anterior cruciate ligament ruptures, tendinopathies like Achilles, Tibialis Posterior and Patellar (Kulig and Burnfield, 2008). The design of joint replacements for degenerated joints is one of the most mature applications of computational biomechanics (Regna N, 2007). In addition corrections of gait and movement disorder are the main objectives of biomechanics and rehabilitation sciences. Recently biomechanics and rehabilitation sciences uses sensors like fiber Bragg gratings (FBGs) applications due to their advantageous properties like small size, light weight, biocompatibility, chemical inertness, multiplexing capability and immunity to electromagnetic interference (EMI). FBG-based sensors demonstrated their feasibility for specific sensing applications in aeronautic, automotive, civil engineering structure monitoring and undersea oil exploration; however, their use in the field of biomechanics and rehabilitation applications is very recent. They are applied for detecting strain in bones, pressure mapping in orthopedic joints, stresses in inter vertebral discs, chest wall deformation, pressure distribution in Human Machine Interfaces (HMIs), forces induced by tendons and ligaments, angles between body segments during gait, and many others in dental biomechanics.(Osman et al., 2012)

Biomechanics in Musculoskeletal Rehabilitation

The biomechanics of the foot and ankle is important to the normal function of the lower extremity. Proper arthokinematic movement within the foot and ankle influences the ability of the lower limb to attenuate the forces of weight bearing. It is important for the lower extremity to distribute and dissipate compressive, tensile, shearing, and rotary forces during the different phase of gait. Inadequate distribution of these forces could lead to abnormal stress and eventual
biomechanics of the foot and ankle have profound clinical applications for injuries due to abnormal force distribution on the foot (Robert Donatelli, 1987). Biomechanics now is playing a great role in replacing artificial leg which can attract all eyes at Oscar Pistorius in the 2012 Olympic game. The biggest story in the 400-meter dash at the London Olympics was about the south African runner Oscar Pistorius who is the “fastest man on no legs” and will be going up against some very strong legs in the 400 and 4x400 relay. He was born without fibulas, leading to double amputation below the knee. He’s done pretty well for himself on his new legs, using cheetah flex foot carbon fiber limbs to get around the track in 45.07 seconds recorded as his personal best time (Blake D. 2012).

In clinical screening biomechanics have great place to assess joint biomechanical dysfunctions and its co-morbidities have been of interest for researchers and clinicians in recent years. Research in the area of knee injury mechanics has elucidated some of the biomechanical predisposing factors that lead to knee injury. Clinicians are still puzzled on how to translate these findings to their clinical practice. Even though, highly instrumented, costly equipment and time consuming data analyses are some of the difficulties of using 3-dimensional biomechanical analysis in the clinics. Several biomechanical lower extremity assessment tools are available and feasible to use in the clinic to guide proper clinical decision making that may impact prevention of knee injuries in the physically active population (Ortiz and Micheo, 2011). Biomechanical principles also provide a valuable perspective to our understanding of the mechanism of injury, rehabilitation and joint replacement of the hip. An understanding of the biomechanics of the hip is vital to advancing the diagnosis and treatment of many pathologic conditions. Some areas that have benefited from advances in hip biomechanics include the evaluation of joint function, the development of therapeutic programs for treatment of joint problems, procedures for planning reconstructive surgeries and the design and development of total hip prostheses (Johnston et al., 1998). A biomechanical model of the thumb can help researchers and clinicians understand the clinical problem of how anatomical variability contributes to the variability of outcomes of surgeries to restore thumb function if alternative kinematic descriptions of the thumb, sensitivity of biomechanical models monitored for the exact musculoskeletal parameter values, good choice of mathematical solution and uncertainties in published musculoskeletal parameter values are avoided (Valero-Cuevas, 2003). The significance of studying the biomechanical properties of ligaments stems have increased the understanding of ligament behavior which helped to identify key ligaments requiring restoration after injury, and have assisted in identifying materials and tissues with appropriate characteristics that can be used as replacements (Chimba et al., 2001). All the above applications are the evidences of how we have to proceed in additional musculoskeletal rehabilitation system by using different mechanical applications.

**Biomechanics in Neural Rehabilitation**

Neural rehabilitation principles and techniques have been developed to restore neuromotor function for restoration of normal physiological movement patterns based on neurological gait rehabilitation techniques like neurophysiological and motor learning (Belda-Lois et al, 2011). The physiotherapist supports the correct patient’s movement patterns, acting as problem solver and this correct patients’ movement pattern will be monitored by gait analysis using biomechanical applications additional sensors and movement monitoring instruments. For example patients with diabetes mellitus and peripheral neuropathy have a high incidence of injuries while walking. Biomechanical analysis of their walking may lead to treatments to reduce these injuries. According to the study on differences in the gait characteristics of patients with diabetes and peripheral neuropathy compared with age-matched controls, subjects with diabetes mellitus show less ankle mobility, ankle moment, ankle power, velocity, and stride length during walking than subjects without diabetes mellitus. The research shows that the diabetes mellitus group subjects appeared to pull their legs forward using hip
flexor muscles (hip strategy) rather than pushing the legs forward using plantar-flexor muscles (ankle strategy) as seen in the subjects without diabetes mellitus (James et al., 1994). Implications for treatment are presented to attempt to reduce the number of injuries during walking in patients with diabetes mellitus and peripheral neuropathy and it should be analyzed and monitored using different sensors.

Assessment of kinematic modeling developed for two to four sensors can track position with an error less than 0.1 cm in a 10 cm movement and can measure angle to 1° and this applications of inertial sensors to monitor the rehabilitation of patients with neurological disorders helps in Preliminary testing and data analysis on healthy volunteers & patients to get additional information based on timing for each movement within a test, trajectory of joints in 3D space, changes in peak acceleration can be an indication of improved function. For example timing for each movement may indicate patient’s ability to grip and hold the object and the limb the range of motion value and time dependence can be used to assess the patient’s response to rehabilitation (Lu Bai et al., 2012).

**Biomechanics in Walking and Running Gait Training**

The gait cycle is defined as the period from heel contact of one foot (for example, the left foot) to the next heel contact of the same foot in other way we call it one stride (Grimshaw et al., 2006). This cycle is broken into two parts, stance phase and swing phase. On the average, the gait cycle is about one second in duration with 60 percent in stance and 40 percent in swing. The stance phase is further divided into an initial double stance, followed by a period of single stance and then a final period of double stance. Double stance indicates that both feet are in contact with the ground; single stance is the period when only one foot is in contact with the ground. When walking, there must be a period of double stance and when running, this period is replaced by a flight phase during which neither foot is in contact with the ground. During the early part of stance phase, the heel is in contact with the ground, progressing to foot-flat during single stance and then to the forefoot contact during the final double stance phase ending with toe-off. This would be the normal contact areas of the plantar surface of the foot with the ground but may vary greatly with pathological gait. For example, equines gait is characterized by the forefoot striking the ground first and then the contact area, progressing to the posterior in some cases while in others the heel never contacts the ground (Sarah et al., 2002). During double stance, the weight is transferred from one foot to the other. During single stance, the center of mass of the body passes over the foot in preparation for shifting to the other limb. Walking has been described as a series of falls from one limb to the other and it is obvious that the greatest danger of an actual fall is during this period of transferring weight. Gate can be measured by electromyography sensor in clinical setting. EMG sensors record the electrical signal produced by a muscle during activation. At the same time it shows the specific timing and relative intensity of muscle effort in larger superficial muscles using surface electrodes and the activity of deeper muscles can be accurately documented by fine wire electrodes (PERRY J., 1998). Like walking gait running gait analysis is done from real time observational gait analysis to the use of high resolution cameras and video recording devices; force plates; computer systems and other laboratory measurement instruments. There are five gait measuring systems they include: Motion analysis, dynamic electromyography, Force plate recordings, energy cost measurement or energetics, and measurement of stride characteristics. Kinetic analysis is related to force production where as kinematics is the measure of movement itself and reflects the effect of kinetics. Gait kinematic analysis is best done in a steady state outside of starting and stopping and require enough space for the subject to start, walk/run, and stop (sheila and Krishna, 2005).

**SUMMARY**

Studying human motion from ancient Greece up to now with the advancement of technology like photographic camera, force plates, video camera, magnetic resonance imaging, bone density scan, electromyography and different sensors could result kinetic and kinematic analysis of gait as well as clinical evaluation and rehabilitation of sport injuries, strokes and osteoarthritis. Now a day
biomechanics in musculoskeletal rehabilitation applied widely on tendenopathies like achilles, tibialis posterior problems, and patellar, force distribution like compression, tensile, shearing and rotary forces during different phases of gait. It also helps in replacing degenerated joints, detecting stress in bones, stress in inter vertebral discs, chest well deformations, force induced by tendons and ligaments, angles between body segments during gait. Biomechanics in neural rehabilitation plays a great roll on patients with diabetes mellitus, peripheral neuropathy and cerebroplasty. It also helps in evaluating and analysis of walking and running gait by the help of gait measurement systems like motion analysis, dynamic electromyography, force plate recorders, energy cost measurements and measurements of stride characteristics.

Adaptable anatomical models including prosthetic implants and fracture fixation devices and a robust computational infrastructure for static, kinematic, kinetic, and stress analyses under varying boundary and loading conditions are applied highly in rehabilitation science. This integrated biomechanical computation creates positive impact on orthopedic education, basic research, device development and applications including clinical patient care related to musculoskeletal joint system reconstruction, trauma management, and rehabilitation. I have provided a concise review of the biomechanical applications for the patients, physicians, physiotherapists and biomechanical engineers in the science of rehabilitation to understand systematic mechanical applications on human body which helps to current and future solutions.

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