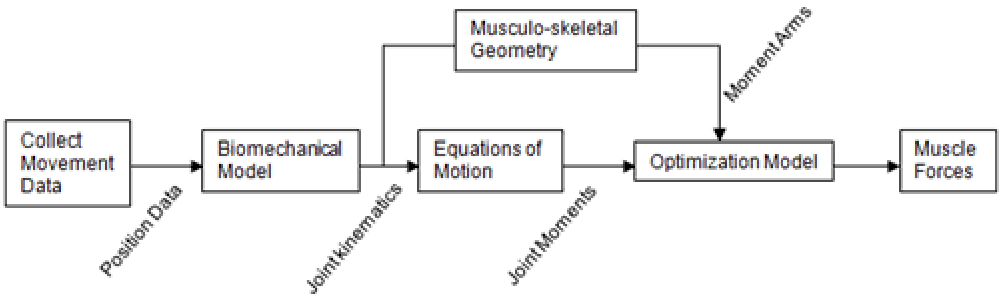
Biomechanics Laboratory | Postgraduate projects

Musculo-skeletal biomechanical modelling

Development of a musculo-skeletal biomechanical model to quantify muscle forces during upper-limb movements. Yanxin Zhang.

The aim of this project is to develop a musculo-skeletal biomechanical model to quantify muscle forces during upper limb movements, which will include a marker based biomechanical model, dynamic equations of motion, musculo-skeletal geometry and an optimization model. The proposed research project has three separate but closely related phases. In the first phase, Magnetic Resonance Imaging (MRI), Kinematics data and electromyography (EMG) data will be collected from 10 subjects to establish baseline data that can be evaluated by the model. In the second phase, the upper extremity will be modelled as a multi-linkage biomechanical system and the equation of motion will be set up to compute the joint moments that are required to produce specified motions of body segment. Subsequently a muscular model will be developed to simulate joint and muscle forces. The kinematic data will be used as input to the model and model parameters will be calibrated based on the data. During the third phase, the model will be evaluated using statistical methods.



Exercise intervention on diabetic peripheral neuropathy

The effect of a lower-extremity neuromuscular exercise intervention on diabetic peripheral neuropathy. Jason Gurney.

Diabetic neuropathy affects a large percentage of those with diabetes. Those who have this complication may lose sensation under parts of their feet, which can be very dangerous, a person with severe neuropathy could step on a nail and not realise it. This sensory loss is critical for key body functions such as reflex responses and balance.

Another complication of neuropathy is the loss of lower leg muscle strength and function. Again, this can be dangerous since we rely on the precise control of these muscles for balance and walking.

These complications, along with others, can lead to dangerous increases in pressures under the foot, both during walking and while wearing shoes. These increases in pressure are the main cause of foot ulcers, and if left untreated, these ulcers can become infected and may end in part or full amputation of the lower leg.
At the Biomechanics laboratory, our research team has been investigating diabetic foot complications since 2003. As part of my Doctoral research, I am interested in discovering more about how we can treat neuropathy more effectively. Specifically, I want to investigate the effect of a specific exercise intervention on the progression of diabetic neuropathy.

Exercise has been shown to improve muscle and nerve function in those with diabetes. However, due to the complications of neuropathy some forms of exercise can be dangerous. The exercise programme in this study therefore consists of low-impact, lower-leg specific exercises. These involve balance exercises and lower-leg strength training, for around 20 minutes, two times per week.

Biomechanical assessments are conducted at various times during the programme so we can find out if the training has been effective. Assessments include muscle strength, sensory threshold, balance, blood glucose, quality of life, dynamic foot structure and pressures under the foot during walking.

Dynamic balance in children with Cerebral Palsy

A study of the effectiveness of a three-dimensional, inverse dynamics, full body biomechanical model in evaluating and rehabilitation dynamic balance in children with Cerebral Palsy. Megan Moreau.

Dynamic stability is the maintenance of upright posture during whole body movement over a changing base of support. This consists mainly of keeping the body's centre of mass within the base of support. Children with cerebral palsy do not have the luxury of normal development and must contend with mastering balance via the control of joints which have developed contractures, deformities and shortened muscles; all of which lead to the use of unique motor function adaptations in order to maintain dynamic stability.

To determine the mechanisms used by children with cerebral palsy a reliable measurement of dynamic balance will be developed, incorporating whole body centre of gravity paths, joint torques and moments, gait kinematics and energy flows. Secondly, that measure will be used to compare normally developed children with those with cerebral palsy to determine the different mechanisms used to balance when overcoming functional deficiencies. Finally, the differences in dynamic balance measures of the children with cerebral palsy both pre-treatment, be they surgical or otherwise, and post treatment will be measured and compared to determine what treatments, if any, will improve the measure of dynamic stability for these children.

Dynamics of freestyle skiing

Dynamics of freestyle skiing – equipment development and implications for injury prevention strategies. Nico Kurpiers.

Presently alpine skiing is one of the most popular leisure activities that can be performed as life-time-sports with approximately 200 million people participating. Freestyle skiing, which now includes moguls, aerials, half-pipe and slope styles, has changed remarkably over the last decade. It has gained new popularity and opened a path for the so-called ‘New School Era’ which includes stylish tricks and spectacular jumps currently dominating skiing magazines and freestyle films.

Each year, skiing causes numerous snow sport injuries involving mainly the knee, specifically the anterior cruciate ligament (ACL). New research is looking at the impacts of freestyle skiing on the body, with a view to design new equipment which will reduce injuries. Nico Kurpiers PhD research project as an international collaboration between New Zealand, Denmark and Germany is currently investigating the effects of modified ski boots on freestyle skiing, ie, moguls and aerials.

The project is carried out in New Zealand, Switzerland and Germany where elite level athletes are tested using a comprehensive biomechanical setup. This consists of multiple synchronised cameras and two force measurement devices worn between the boot and the ski. Additionally, pressure insoles are worn within the shoes to draw a comprehensive ‘data picture’ of the loads experienced in skiing. This study is unique in its complexity and will provide new insight into injury mechanisms and most importantly the effect of modifications to equipment.

Fig.1 - Force measurement device Fig.2 - Freestyle skiing participant

Physical Robot-Human Interaction

Physical Robot-Human interaction for performance based progressive robot-assisted therapy. Shane Xie, Andrew Pullan, Bruce MacDonald, Gordon Mallinson and Yanxin Zhang.

Recent development of robotics and advanced control technology has provided efficient tools for the development of new medical devices. While skilled therapists or surgeons can achieve good results with even rudimentary equipment, the maximum effectiveness of their existing "toolbox" is rapidly being reached. New assistive tools are needed to improve productivity, enhance medical outcome and reduce potential risks. Our research suggests that robotics and information technology can transform clinical practice from its present basis in manual operations to a more technology-rich operation. This situation creates a pressing need for new therapeutic strategies to increase productivity while optimizing the quality of care.

This research aims to investigate the underlying fundamental science behind physical human-robot interaction. This includes the understanding of the biomechanics of bone-muscle system, motor learning, and neuro-recovery processes. A new performance-based impedance control algorithm, which is triggered via speed, time, or electromyography (EMG), will be developed based on the understanding and feedback of the bio system. The main goal of this research is to set up the foundation for the development of a new class of interactive, user-friendly robotic devices that can assist, enhance, and quantify rehabilitation.

This research is to investigate the following four fundamental issues:

1. The technological evolution of machines for physical exercise
2. New Methods for evaluation of rehabilitation performances
3. Advanced control methods for human robot interaction
4. Biomechanics modelling of biosystem.

The research will start with lower limb rehabilitation but the results will contribute to the development of other medical devices that require physical interaction with human.

The project is to set up a foundation for future funding applications from the Medical and Rehabilitation Robotics group, and it will be important to the development of the group. The group has developed many research prototypes especially in the medical devices area. A prototype rehabilitation robot has been set up to control interaction force in three degree of freedom and this robot will be used as a platform for this research. The budget is made up of people cost involving a one-year postdoctoral fellow and equipment cost.

New Technique for Studying Sports Injury

New technique for studying the etiology of sports injury. Yanxin Zhang.

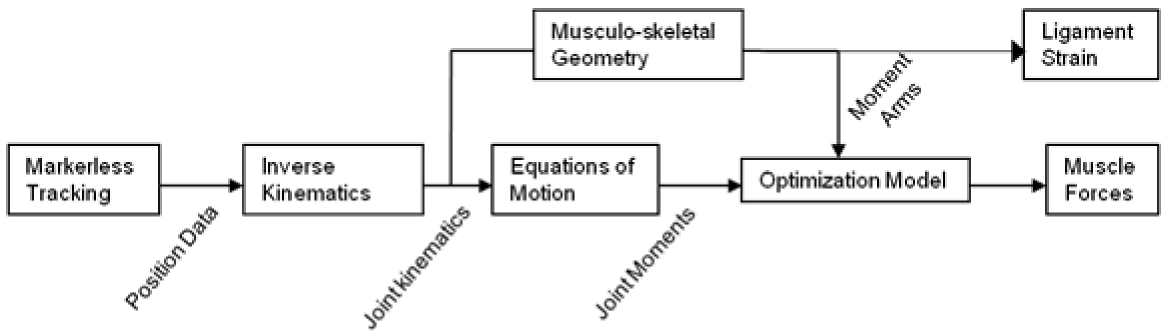
Sports injuries cost the New Zealand taxpayer $69 million in 2006 (ACC) and the trend shows no sign of this number decreasing. These costs include those of treatment, rehabilitation, and injury prevention programs. Unfortunately, detailed etiologies of many sporting injuries are larger unknown because of the absence of a controlled testing environment at the time of injury. Quantification of the ligament strains and muscle forces is essential in understanding the injury mechanisms and it can provide information to establish injury prevention programs or clinical criteria for rehabilitation and treatment. Development of a technology that could be used in the field could provide the necessary information about the cause of injury that could then be implemented in injury prevention programs. Additionally, this much needed information could test the efficacy of existing treatment and rehabilitation programs as well as provide insight into the development of new ones.

Further developments in motion capture technology (vision-based human pose recognition system from markerless tracking of movement) and computational methods provide techniques to measure three dimensional human motions with high accuracy and perform simulations of complicated musculoskeletal systems. Many sporting events are already recorded with multiple camera views. We propose to use video records of on-field injuries and with the proposed vision-based human pose recognition method and musculoskeletal simulation to quantify soft tissue behaviour at the time of the injury.

The proposed research will consist of the following main components:

1. Development of a markerless tracking system that can create accurate body segmentation for the production of joint kinematic data
2. Development of a generic lower limb musculoskeletal model, which includes skeletal geometry of each bone in the lower limb represent the anthropometry human subject.

A flow chart is shown in the following figure:



This project aims at applying and deepening existing research in:

1. Biomechanical simulation
2. Vision-based pose tracking.

Both disciplines have reached a competitive level of depth at the participating groups in the departments of Exercise Sciences and Computer Science at The University of Auckland, and by combining efforts within the framework of this project, research in both areas would obtain new inspirations and possibilities to contribute on a wider, multi-disciplinary scale towards a solution which would be at top-level compared to international activities in those areas. The proposed research will provide information to estimate the injury potential of a certain type of movement or establish clinical criteria for rehabilitation. New interdisciplinary research plan in biometrics, biomechanics, and computer vision will be promoted by the developed research skills from this project.

Gait Identification

Gait identification. Sharon Walt and Yanxin Zhang.

The study of personal identification technologies is required for various security applications, but also for medical studies, eg, separating between common and individual behaviour, or, for example, for the unique animation of characters in the movie industry.

While there are known limits of present biometrics technologies, multi-modal solutions and biometric technologies are research directions to overcome those limits. Until recently, identification mostly relied on fingerprint, facial and iris biometric techniques but because humans have an apparent inherent ability to recognise individuals by their walking gait attempts have been made in recent years to use certain kinematic gait parameters in developing unique identification protocols.

Studies have focused on either 2D representations of the lower body, temporal-spatial parameters such as walking period, or the analysis of image silhouettes. The field of clinical gait analysis has shown that gait kinematics (joint angles and derivatives) are highly repetitive and unique, and are consistent enough from day to day for making significant, clinical decisions. However, due to the subtle nature of the individual differences, unique identification is more challenging and requires a more advanced biomechanical model-based approach which incorporates whole-body 3D kinematic gait parameters, measures of movement coordination and image parameters.

Kinematic gait analysis is a relatively routine endeavour in a dedicated motion capture laboratory, but to date, accurate 3D kinematic representations of walking gait in public spaces (known as markerless tracking), using common surveillance cameras, has not yet been possible. This is despite good progress in markerless pose recognition, also supported by progress in neighbouring fields in computer vision [stereo analysis, video processing, Human Machine Interface (HMI), and so on].

My proposed research will initially consist of two parallel (but closely interlinked) lines of inquiry:

1. Development of a minimum set of parameters, including kinematic, movement coordination, and/or image parameters, to produce a unique gait identifier
2. Development of a markerless tracking system that can create accurate body segmentation for the production of joint kinematic data. Both lines will then be combined for demonstrating a system for 3D-gait-based biometrics, at a distance.