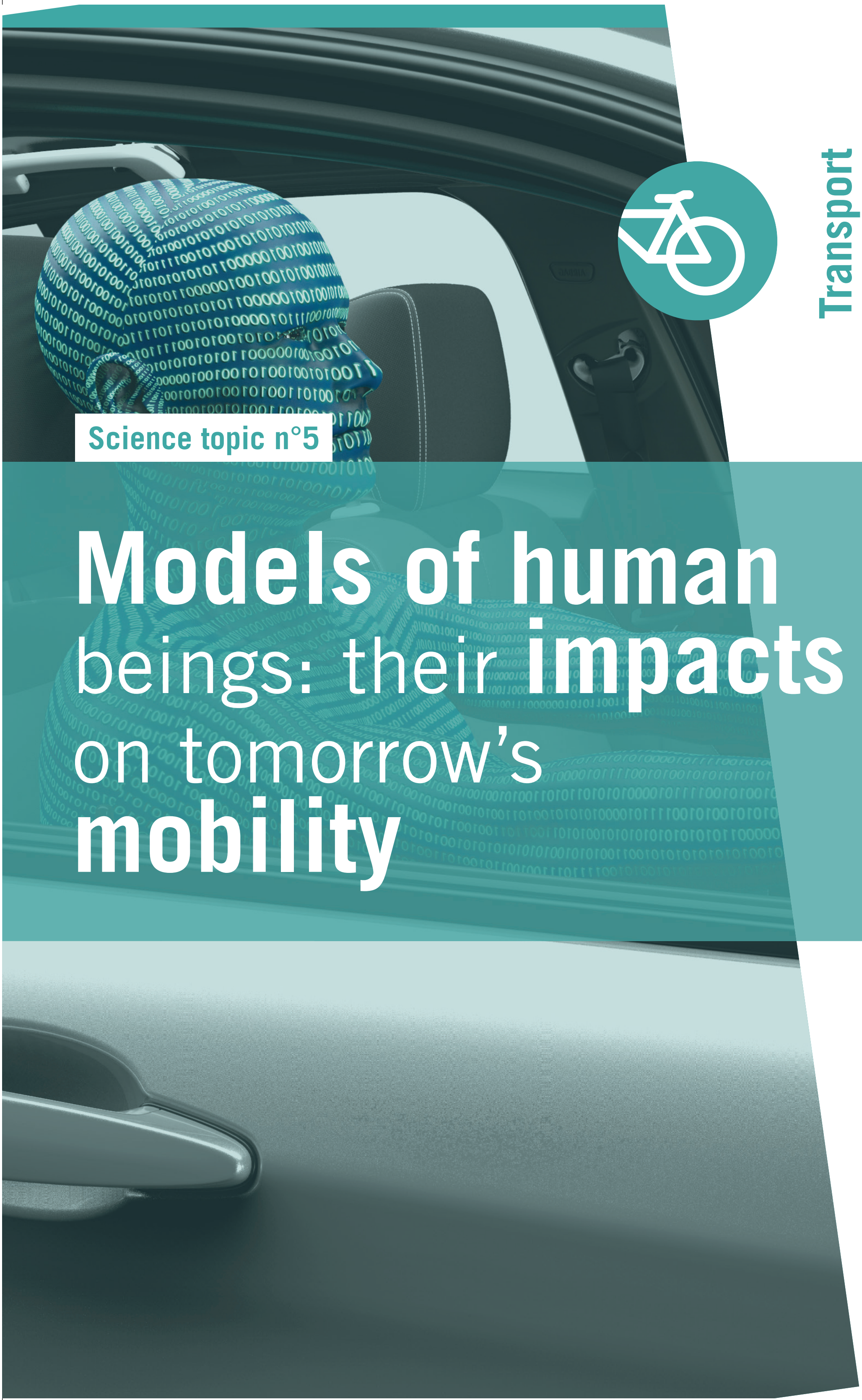


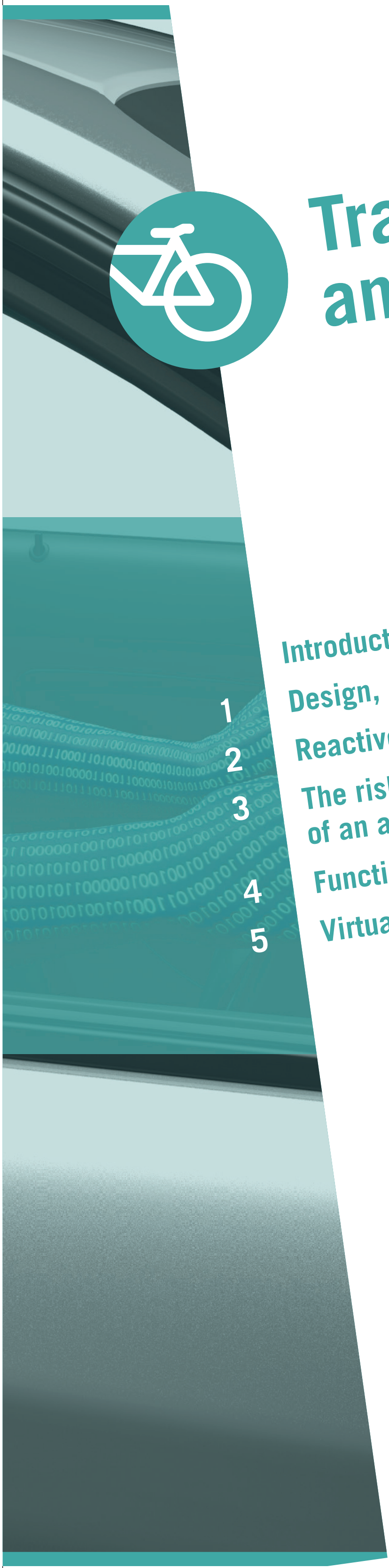
Transport and mobility

Science topic n°5

Models of human beings: their impacts on tomorrow's mobility

Science topic n°5

Models of human beings: their **impacts** on tomorrow's **mobility**



Transport and mobility

Ifsttar has become Gustave Eiffel University from the 1st of january 2020

Université Gustave Eiffel

MODELS OF HUMAN BEINGS: THEIR IMPACTS ON TOMORROW'S MOBILITY

By Philippe Vezin,
Director of the LBMC[1] (2007-2015)
TS2[2] Department

Mobility is a societal issue. Travelling is a normal day-to-day activity which everybody wishes to be safer, more comfortable and accessible. Travelling is also an important factor of socialisation, allowing people to avoid isolation and exclusion.

Changing transport means and systems

Everyday life is changing with the rise of new modes of transportation, the arrival of the automatic or autonomous cars, the emergence of soft transport modes and the increase of the public transports' use. Going with these changes is a major concern of the sector actors whether political, industrial or academic.

The complexity of the system to be studied, which has absolutely to take into account the individual and theirs particularities, can only be tackled with a massive use of the numerical simulation and virtualization allowed by the increased power of informatics.

Models that take account of the complexity of being human

Modelling the human being, who is at the centre of the system, represents a real scientific challenge for us today, even if we consider only the physical and biomechanical dimension[3]. There is a considerable degree of morphometric variability[4], as well as major physical and mechanical differences from one individual to another. These characteristics are also changing over time, as a result of ageing, or simply physiology as a result of the individual's state of health at a given time.

Moreover, the different components that make up an individual's physical mobility, or the various events which can occur during a journey require a variety of modelling approaches.

For this reason researchers at the LBMC[5] are exploring various approaches to modelling the human being in order to provide those who require them (vehicle designers, surgeons etc.) with tools for evaluating and predicting the biomechanical behaviour of human beings. The models in question take account of both inter- and intra-individual variability.

These tools allow us to construct specific models that provide a more faithful representation of the patient. They are also of assistance in the fields of post-traumatic and pathological surgery. Other approaches may be used in order to design protective equipment or the vehicle passenger compartments (ergonomics) in order for them suitable for the largest possible number of individuals.

New tools to anticipate the travels

Each application requires its own model. These are used throughout the travel cycle to better anticipate thereof. From simply the walk, firs mode of travel, up to the post-accident repair, the biomechanical simulation tells the story of your travel.

First of all, going to the chosen mode of transport, access and take place in the vehicle. This activity could be more ergonomics and comfortable thanks to a new design also taking into account the specific characteristics of reduced mobility people.

The vehicle and the on-board systems, thanks to the pre-crash simulation tools, could be designed to better prevent, mitigate or avoid an eventual crash.

Predictive models of injuries will allow the development of smart and efficient protective systems to reduce at the most the severity of the impact.

Finally, your own model, that means a patient-specific model, will help the surgeons for a better diagnostic and evaluation pre and postoperative to optimize the surgery and the rehabilitation.

1. LBMC: Biomechanics and Impact Mechanics Laboratory
2. TS2: Transport, health, safety Department
3. Human body mechanics
4. Quantification of shapes
5. The Laboratoire de Biomécanique et Mécanique des Chocs is a joint research unit between Ifsttar and the University Claude Bernard Lyon 1 http://www.lbmc.ifsttar.fr/en/the-institute/ts22/laboratories/lbmc/

Video (FR)

Why do we model the human being?

Listen to Philippe Vezin
from the LBMC
Département TS2 (2007-2015)

1 IMPROVING THE COMFORT AND ACCESSIBILITY OF TRANSPORT VEHICLES

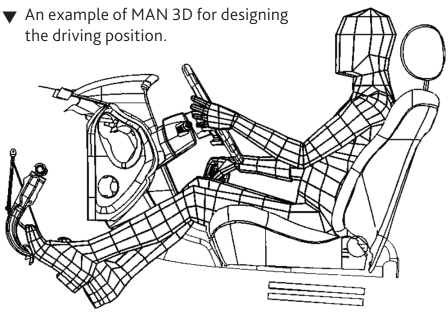
By Xuguang Wang,
Senior researcher
TS2[1] Department, LBMC[2] Laboratory

The "Biomechanics[3] or ergonomic[4]" team at the LBMC[2] is developing tools and techniques for observing, understanding, evaluating and simulating human motor activity. The team focuses on motor activity during the use of transport facilities and vehicles with a view to improving user comfort and accessibility. Numerical dummy models, which are a computerised model of a human, are one of the simulation tools and are becoming essential in order to evaluate the ergonomics of a product or a workstation. Evaluation of this type can contribute to the design phase, simplifying the production cycle in order to improve industrial competitiveness.

Considering ergonomics within vehicles

Today's numerical dummy models for ergonomic simulation are based on a three-dimensional geometrical model of the external surface of the body and a simplified representation of the internal skeleton. Starting at the end of the 1980s the LBMC in collaboration with the motor vehicle manufacturer Renault, developed one of the first European numerical dummy models, Man3D. Since then, the laboratory has been involved in bilateral collaborative projects with motor vehicle manufacturers (PSA, Renault Trucks, and more recently Toyota Motor Europe and Ford). In this connection, the LBMC has been a major player in two large-scale European projects on human digital modelling (REALMAN, 2001-2004 ; DHErgo, 2008-2011, which it coordinated).

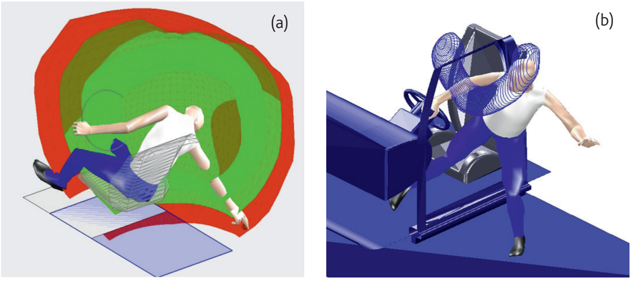
▼ An example of MAN 3D for designing the driving position.



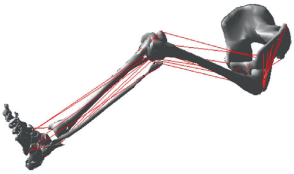
The ability to predict movement and discomfort

In addition, a new methodology has been developed to simulate movement and evaluate the resulting discomfort. At the request of Renault, this innovative methodology has been implemented in a software package known as RPx[5]. A large database of movements has been created, ranging from a simple movement to press a button on the dashboard to vehicle ingress/egress movements.

More recently, the human digital model has acquired muscles, in particular in its legs. This means it can now measure muscular effort such as that involved in declutching. Other models are currently being developed which perform more precise simulation of interaction between the human being and the environment (e.g. buttock/seat interface).



◀ Simulation performed by the RPx software package.
(a) Simulation of several reach envelopes.
(b) Simulation of vehicle ingress/egress movement with the volume swept by a body segment.



◀ Musculoskeletal model of the leg developed by the LBMC to estimate the muscular effort required during declutching.

1. TS2: Transport, health, safety Department
2. LBMC: Biomechanics and Impact Mechanics Laboratory
Laboratory of Impact Mechanics and Biomechanics is a research unit that is jointly managed by IFSTTAR and Université Claude Bernard
https://lbmc.univ-gustave-eiffel.fr/
3. “Biomechanics is the study of the structure and function of biological systems [...] by means of the methods of mechanics” Wikipedia definition
4. “Ergonomics is the practice of designing products, systems, or processes to take proper account of the interaction between them and the people who use them.” Wikipedia definition
5. Realman Program eXtension, extends the European REALMAN project and sets out to develop software which would enable Renault engineers to integrate motion simulation in the car design process.

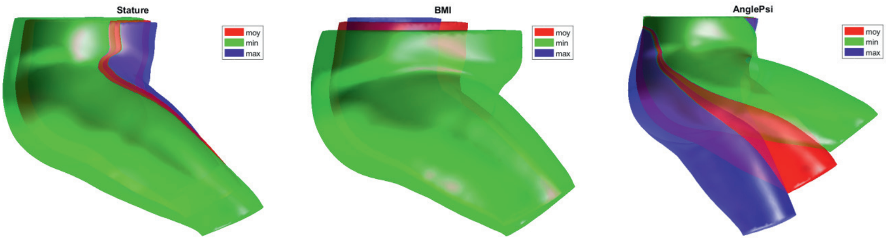
Article Update: septembre 2017

IMPROVING THE COMFORT AND ACCESSIBILITY OF TRANSPORT VEHICLES (END)

Parametric modeling of human body and seating discomfort

How to take into account the variability in human body dimensions is one of the questions posed when designing a product like an automobive or airplane seat. LBMC has developed a parametric surface model of the buttock-thigh complex recently in collaboration with Zodiac Seat France, leader of the airplane seats. In parallel, LBMC is working on seating discomfort criterion in a national collaborative project supported by DGAC[13] which is aimed to develop more comfortable, accessible and ecological airplane seats in the future. A new unique experimental seat was built for experimentally investigating sitting biomechanics.

6. Directorate General of Civil Aviation, project n ° 2014 930818.



▲ Parametric surafce model of the buttock thigh complex with stature, weight and thigh flexion angle as predictors.

Video

Further readings

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DHErgo: Digital Humans for Ergonomic Design of Products. European funded Project SCP7-GA-2008–218525

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Article Update: septembre 2017

IFSTTAR'S COLLECTION
February 2015

2 TAKING ACCOUNT OF HOW INDIVIDUALS REACT TO A RISK

By Thomas Robert,
Researcher
TS2[1] Department, LBMC[2] Laboratory

In most cases, a person who is facing an imminent risk (loss of balance, forthcoming impact, etc.) has the time to perceive it and react.
When a road traffic accident happens, drivers generally see the approaching danger. This gives them time to try to brake in order to avoid the accident or at least to stiffen up in order to better withstand the impact. In the same way, passengers who are standing in the Metro can lose their balance during emergency braking. But in most cases they will have time to try to regain their balance or at least try to limit the impact of a fall.
When these reactions are appropriate, they make it possible to avoid the accident, or limit its consequences. However, they can also have the opposite effect and generate an additional risk. A good example of this is when a pedestrian avoidance system[3] is activated in an emergency and causes a secondary accident when the first could have been avoided otherwise.
Studying these reactions and integrating them within digital human models is therefore of major importance. The LBMC is therefore engaged in several research projects to better identify hazardous situations and better protect individuals.

Analysis of movement in pre-crash situations

How do pedestrians – young or elderly – react when a high speed vehicle suddenly appears when they are crossing the road and threatens to hit them? And what are the possible consequences of this reaction?
To answer this question, IFSTTAR has set up the following experiment :
Young and elderly subjects take turns to move around a virtual environment which simulates a street with traffic consisting of a flow of vehicles. When one of the pedestrians is crossing the street, the simulator generates a high speed vehicle, which is accompanied by the noise of a crash. The reaction of the pedestrians is recorded with a motion analysis device similar to those used in the video games or cinema animation industry.

This experiment collects data about the posture of subjects and their muscular activity[4] at the time of impact. This data is then integrated within the various injury prediction models in order to estimate whether these reactions tend to reduce or increase the risk to which the pedestrian is exposed.

Modelling balance control mechanisms

Keeping balance when standing is a relatively difficult task. This is particularly true in an unstable environment such as a public transport vehicle.
Falls are, in fact, one of the most common causes of injury. Elderly people often mention that the fear of falling prevents them from using public transport. This observation raises many questions: to what risk of falling is an individual exposed according to their capacities and the

interference with balance they experience? Can they recover their balance, and if so how?

To answer these questions, the LBMC has been working for several years on modelling balance control and recovery mechanisms. The models it has developed consist of a mechanical representation of the human body and controllers which determine the necessary recovery actions[5]. They are then tested on previously collected experimental data collected in the course of experiments conducted on volunteers.

▼ Modelling balance control mechanisms.

1. TS2: Transport, health, safety Department
2. LBMC: Biomechanics and Impact Mechanics Laboratory
3. Exemple du système développé par Toyota
4. Anurag Soni, Thomas Robert, Frédéric Rongieras, and Philippe Beillas. Observations on pedestrian pre-crash reactions during simulated accidents. Stapp car crash journal, 57:157–183, 2013.
5. Zohaib Aftab, Thomas Robert, and Pierre-Brice Wieber. Predicting multiple step placements for human balance recovery tasks. Journal of Biomechanics, 45:2804 – 2809, 2012.

▼ Example of different postures observed at the time of the virtual impact.

3 THE RISK OF INJURY AS THE RESULT OF AN ACCIDENT

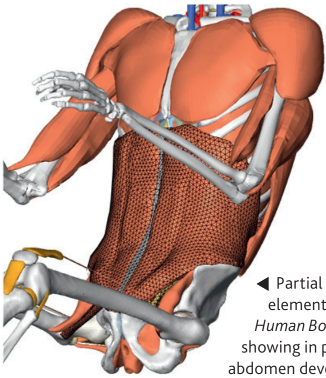
By David Mitton,
Director of LBMC[1] Laboratory
TS2[2] Department

Since the beginning of the years 2000, the Laboratory of Impact Mechanics and Biomechanics (Laboratoire de Biomécanique et Mécanique des Chocs – LBMC) started its involvement in European projects aimed at developing models of the human body. Since that time, this modelling research has taken on a global dimensional with the setting up of a consortium (Global Human Body Model consortium, GHBMC) bringing together the majority of the world's motor car manufacturers. This consortium asked academic research centres to develop models of parts of the human body and assemble a head-to-toe model. The LBMC has been recognised as « Abdomen Center of Excellence », and then developed the abdominal part of the model. The first full version of the model represents a man of average height. Since 2013, a licence for this model is available free of charge to all academic institutions. The next phases of the project aim to develop models for other population groups in order to cover all individuals, including children.

Models based on medical images

The model of the human body, which includes internal organs such as bones, the heart, the liver, etc., was based on medical images. This permits the construction of morphologically realistic models. Some forms of medical imaging also allow to investigate the influence of subjects' posture on the form and position of their internal organs (Lafon *et al*. 2010).

For transport accident applications "average male" models are usually used. However, specific models need to be developed to represent different population groups (Poulard *et al.* 2012). Research, at the European level, is working towards the development of tools to personalise and position human body models (for example the PIPER project). These will allow to model the bodies of children of different ages and adults of different sizes. The effect of age, during growth then during ageing, should also be taken into account. Nondestructive methods with the potential of exploring this aspect have been evaluated (Mitton *et al.* 2014).



◀ Partial view of the finite element model (*Global Human Body Model*, GHBM), showing in particular the abdomen developed in the Laboratory of biomechanics and impact mechanics (IFSTTAR-UCBL).

The ability to create specific models is also a necessity for health-related research. When they are based on medical imaging such models can be more easily personalised, for a given patient. This is one of the topics covered by the laboratory of excellence[3] PRIMES (Physics, Radiobiology, Medical Imaging and Simulation

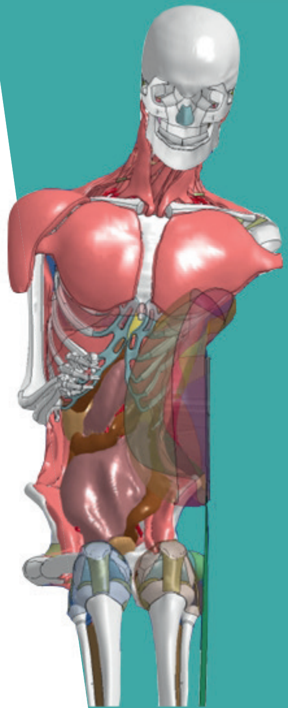
– Physique Radio biologie Imagerie Médicale et Simulation) that brings together 16 research laboratories in Lyon, Saint-Etienne, Grenoble and Clermont-Ferrand, whose the LBMC.

Advanced models to predict injury risk

Once the models have been constructed, their performance must be validated under a variety of loads. Initially, the response of the models is compared with experiments conducted on isolated body segments in laboratory (Vezin *et al.* 2009). The purpose of these comparisons is to validate the external behaviour of certain parts of the body.

In addition to the external behaviour, internal and local evaluations (Helfenstein-Didier *et al.* 2016) are necessary to assess the realism of the models. A model's responses, in terms of local stresses and strains, may be compared with the experimental data. This complex phase can, among other things, allow to define injury criteria. The data are nevertheless limited.

Research at the international level is continuing to improve the predictive capacity of these models. Ultimately, the objective is for the models to predict injuries in the case of an accident and to evaluate protection systems.



▲ Abdomen of the finite element model (*Global Human Body Model*, GHBM) under loading.

1. LBMC: Biomechanics and Impact Mechanics Laboratory
2. TS2: Transport, health, safety Department
3. Labex : Research funding bodies set up as part of the government future investments (Investissementsd'Avenir) programme.

Pour aller plus loin

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Credit: GHBMC

Article Update: septembre 2017

4 OPTIMISING FUNCTIONAL REHABILITATION

By Raphaël Dumas,
Senior researcher
TS2[1] Department, LBMC[2] Laboratory

In the last few years international research, particularly in Europe, has been facing the challenges raised by the virtual patient and digital medicine[3].Biomechanical models[4] of the human body can be personalised using medical imaging and result in better patient care. These models can represent the skeleton, the organs or cells, with varying levels of complexity.

In the case of physical and rehabilitation medicine, in particular with regard to the recovery of optimum motor function after a transport accident, the best tools are models of the musculoskeletal system. These biomechanical models assist the analysis of movement, which is a clinical examination recognised by the health-insurance system[5]. They therefore help to provide medical care which is increasingly personalised and improve the evaluation of the medical service that is provided.
For example, in the case of an amputee or a person with a spinal cord injury, the best possible selection and fitting of an artificial limb or a wheelchair[6] have a considerable influence on the recovery of mobility and autonomy in both day-to-day and occupational life.

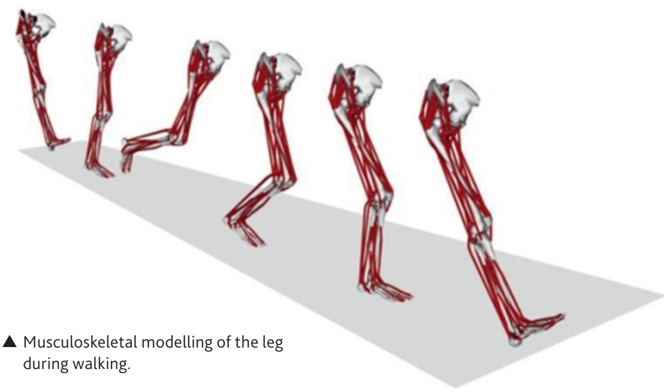
Biomechanical modelling for improved diagnosis of functional capacities…

Such models of the musculoskeletal system provide a very large volume of data which cannot be directly measured. It can be used to guide the rehabilitation team (rehabilitation doctors, limb-fitters, physiotherapists, occupational therapists, etc.) in their diagnosis and care of an individual with a motor disability.

The human body is modelled by a set of rigid segments, mechanical links and cables. Importantly, information provided by these biomechanical models canshow the energy expenditure that is necessary to move and the stresses which are applied to bones, joints, ligaments and tendons[7]. This information provides a unique insight into a patient's functional capacities, particularly those which had been impaired and then restored after an accident.

… and achieving a more complete recovery of mobility

Motion analysis and models of the musculoskeletal system thus help to optimise recovery of motor dysfunction by providing an objective evaluation of the immediate effect of a re-education programme or the fitting of an artificial limb.
This clinical examination and the biomechanical modelling can reveal compensation and excess stresses in uninjured limbs, which will ultimately lead to secondary musculoskeletal disorders. This evaluation, carried out in the course of the most difficult activities performed during daily life, (such as moving on a cant or a slope or negotiating a step) helps identify when mobility has been recovered.



▲ Musculoskeletal modelling of the leg during walking.

Transport and mobility

"The human body is modelled by a set of rigid segments, mechanical links and cables."

1. TS2: Transport, health, safety Department
2. LBMC: Biomechanics and Impact Mechanics Laboratory
3. IFSTTAR belongs to the VPH Institute which fosters integrative biomedical research at a European level.
4. "Biomechanics is the study of the structure and function of biological systems [...] by means of the methods of mechanics" Wikipedia definition
5. Abbreviated procedure sheet for the Three-dimensional analysis of walking using a force platform.
6. The Laboratory of Impact Mechanics and Biomechanics (LBMC) has taken part in an ANR-funded national research project. This initiative has led to the publication of book on choosing and adjusting a manual wheelchair. More about this book.
7. A musculoskeletal model of the arm has been developed at the Laboratory of Impact Mechanics and Biomechanics (LBMC) by FlorentMoissenet, Laurence Cheze, and Raphaël Dumas and validated by measurements made on patients with an instrumented knee replacement.

Pour aller plus loin

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Credit: Ifsttar

Article Update: septembre 2017

IFSTTAR'S COLLECTION
February 2015

5 USING VIRTUAL TESTS

By Jean-Pierre Verriest,
Emeritus researcher
TS2[1] Department, LBMC[2] Laboratory

"Numerical human body models have now reached a satisfactory level of development."

Essential regulatory and consumerist tests

The aim of a test is to make sure that a product complies with a set of safety and/or quality specifications that are laid down in a standard or a regulation[3]. In the case of human protection, regulatory tests consist of subjecting a vehicle to certain crash conditions and assessing that the risk faced by the potential human casualties inside the vehicles is below a limit specified by the regulations. Consumerist tests (such as EuroNCAP set out to measure the effectiveness of protection measures and allocate scores (stars) to the tested products. In the case of cars, the full-scale tests are destructive ("crash tests") and have a cost which is not negligible. In aeronautics, the cost of a test on a real plane is completely prohibitive consequently other test methods have been developed.

The benefits of numerical simulation

Advances in mathematical modelling, and in particular the continuous increase in computing power, mean that we are now able to simulate the behaviour of more and more complex objects with affordable computing times.

Numerical simulation is beneficial, particularly in terms of costs. These are mainly related to the development of the model of the tested product. As soon as the model is available, each simulation is inexpensive to perform, making it possible to test a very large number of situations without a major increase in the budget. However, in the case of physical tests each new test requires a financial investment.

Numerical simulation has been used for some years in the automotive industry to test products during the design phase. It is used at all stages of the process from single components through subassemblies to the entire vehicle. At the most important stages the results of simulation are validated by real tests.

During the design phase simulation considerably reduces the number of physical tests. This limits the cost of manufacturing prototypes which are destined for destruction.

What role for the virtual human?

Until now, simulation of crash tests was performed with a numerical model of the crash test dummies (used in real crash tests). Numerical human body models have now reached a satisfactory level of development[4].

They will therefore gradually replace the models of the dummies. However the validation process[5] is much more difficult than for an inert object such as a dummy.

Their use in a regulatory context is not envisaged for the next 10 years[6]. In order for this to be done, numerical simulation with models of manikins have proved its feasibility and cost-effectiveness.

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1. TS2: Transport, health, safety Department
2. LBMC: Biomechanics and Impact Mechanics Laboratory
3. A regulation lays down a legal obligation which must be complied with, whereas adherence to a standard is a voluntary act that guarantees a certain level of quality or performance.
4. A global project that brings together all motor vehicle manufacturers and some research centres of excellence has developed the most recent generation of numerical model for the human body: http://www.ghbmc.com/
5. Its abdominal model was developed by the Laboratory of Impact Mechanics and Biomechanics (LBMC), a research unit that is jointly managed by IFSTTAR and Université Claude Bernard Lyon 1.
6. The validation of a model is based on comparing the results of simulation with the results of real tests.
7. A European project that involves collaboration between motor vehicle manufacturers, design software publishers and research centres including the Laboratory of Impact Mechanics and Biomechanics (LBMC) has recently laid down the basis for a virtual test procedure.

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