summary

projects

High-flying quality
Safety travels on the bus
Goals on artificial turf: more lasting and sustainable
Point-of-sale shoe customisation
Making classic footwear more flexible
Who says that video games are not for older persons?
The Aquarius amphibious marine wheelchair, back on the beach
Assessing hand capacity objectively
Ergonomic seats for rope access works
The purpose of this project was to develop a software tool for AIR NOSTRUM that would allow it to manage its on-board service in a people-driven way. The ultimate goal was to meet demand by means of an optimal fit between client needs and requirements and available resources. This objective was achieved by analysing the quality of AIR NOSTRUM’s on-board service from the users’ perspective by applying people-driven innovation methodologies. Thanks to the study results, it was possible to ascertain the importance of emotional factors that explain the perception of service quality and the on-board satisfaction of AIR NOSTRUM passengers. Moreover, the resources that influence this perception were detected, obtaining algorithms and guidance procedures for AIR NOSTRUM’s decision-making in resource management.

**INTRODUCTION**

In modern-day markets, if companies want to be competitive they must consider their clients in all the actions they implement. By doing so, they will be more likely to successfully define and carry out objectives and innovation. To this end, in one of its latest R&D projects, AIR NOSTRUM commissioned the services of the Instituto de Biomecánica (IBV), targeting a People-Driven Innovation model. In this model people are the main focus and play a doubly significant role: on the one hand, as end users of the products and services, and on the other as sources of information and opportunities for innovation.

In the current context, the main problem faced by airlines is a suitable management of their resources that will permit them to adjust the offer of services to increase their own profits and benefits for their clients. Therefore, the objective of the study was to give AIR NOSTRUM an integrated process and a computing tool to manage its on-board service on a people-driven basis, enabling it to satisfy demand by means of the suitable adaptation of available resources to client needs and requirements.

Although previous studies have shown that on-board service quality is one of the key factors in attracting and maintaining clients, air companies do not always manage to assign suitable resources to attend to them. For this purpose, an analysis of AIR NOSTRUM’s on-board service quality was conducted from the standpoint of the users of this service, identifying the elements that impact this perception.

**People-Driven Innovation**

The process of analysis of on-board service quality was performed through the application of People-Driven Innovation methodologies (Methodologies IOP). (Figure 1)
First of all, the emotional factors involved in the perception of quality of the service from the user’s standpoint were identified, as well as the most relevant design elements of the service related to their satisfaction/dissatisfaction. To achieve this, the user’s opinion of the service was analysed by means of an ethnographic study, plus information from AIR NOSTRUM’s Passenger Cabin Crew (PCC), by means of an expert focus group. This information was subsequently validated in a quantitative study with a sample of 400 interviews performed on the company’s short flights by means of an optimised factorial design. After the quantitative study, the importance of the factors and the level of satisfaction of the users in each one of them were obtained, as well as the level of influence of each one of the service’s resources in the satisfaction.

Moreover, algorithms and guiding procedures have been developed for decision-making by AIR NOSTRUM in the management of resources as a function of passengers needs and satisfaction in the different factors that impact the perception of on-board quality. These algorithms were implemented in an IT tool that makes it possible to configure AIR NOSTRUM’s on-board service quickly and satisfactorily as a series of resources that adapt to the needs, preferences and characteristics of the different passenger profiles.

The AIR NOSTRUM personnel can access the application via the web, through a simple and user-friendly interface. Once in it, it is possible to obtain information on current services and/or design a new service. For this purpose, the core of the application accesses an updatable data base that contains the information about the on-board surveys that AIR NOSTRUM has administered to users to rate service quality. The application processes these data and displays, among other results, the level of satisfaction and service quality factors.

Figure 3 summarises the operation and design of the application.

**Home (1):** This is the first screen the user sees and from it they can access:

-- Diagnosis of the on-board service: A form field appears where the type of fleet can be indicated, and the flight number and date may be entered. The associated arrow is used to access the diagnostic screen (2).

-- Configuration of new services: The associated arrow is used to access the configuration screen (3).

**Diagnosis of the service (2):** This screen is divided into 2 parts. The left part contains the fields for running the search. A fleet, flight and a specific seat can be selected.

The characteristics of the existing service for the search performed are displayed on the right: map with the location of the seats, flight characteristics, services offered, problems arising (faults, turbulence, changes of plane, heat discomfort), the level of general satisfaction, etc.

There is a button for providing further information next to the level of satisfaction (2.1).

**New tool for satisfying Air Nostrum users**

An user-friendly IT tool was developed to configure the AIR NOSTRUM’s on-board service rapidly and satisfactorily as a
Satisfaction with fleet/flight/seat (2.1): This screen provides information about satisfaction with on-board quality factors. For each factor the information can be extended and the related reasons be ascertained, and user comments are even available.

Configuration of the new on-board service (3). This screen is used to configure the design elements of the new service. The design elements that appear are: class (business-tourist), flight time, pitch, favourite seat, reclining seat, window, catering service, blanket, press, luggage compartment, adjacent passenger and turbulence.

After the elements have been configured and the arrow selected, the graphic information is provided on levels of general satisfaction and by factors that the service provided would generate in the user (3.1.).
> **CONCLUSIONS**

The on-board service management system developed by means of methodologies IOP makes it possible to collect user opinions systematically over time to reflect the effect of changes in the on-board service and subsequently react very quickly. Thanks to this system, the AIR NOSTRUM company fulfils its quality commitment, maintaining the maximum level of passenger satisfaction and making it possible to improve the company’s competitiveness.

![Figure 5. Definition of new on-board services.](image)
Safety travels on the bus

Andrés Soler Valero¹, Carolina Soriano García¹, José S. Solaz Sanahuja¹, Elisa Signes i Perez¹, Ana L. Olona Solano², Antonio Barreiro Bravo³

¹ INSTITUTO DE BIOMECÁNICA DE VALENCIA
² CENTRO ZARAGOZA
³ CARROCERA CASTROSUÀ S.A

Introduction

At the moment there are different public transport vehicles on the market with safety solutions in place basically targeting seated users. However, standing passengers are still the most vulnerable. The importance of the problem of falls in transport is clear, and is particularly relevant in older people. More specifically, falls associated with transport account for 10% of total falls in this group.

The SAFEBUS project aims to cover this gap on the market by offering a safer and more user-oriented integrated system that seeks to prevent or avoid accidents and the injuries associated with the falls of standing passengers or with passengers being knocked down in the areas for getting on or off the bus.

For this purpose, its objective is the development of advanced safety systems, both active and passive, for application in city buses (Figures 1 and 2) that will offer users greater safety and comfort in their travel.

Development

The following plan of work was implemented to carry out the technical work to fulfil the project objectives (Figure 3). To date, phase 1 has been completed and the execution of phases 2 and 3 is under way.

Public transport by bus in cities is designed, generally speaking, as a succession of stops where passengers get on and off the vehicle according to their destination, and where users may travel either standing or seated. These peculiarities of urban transport mean that when buses stop, the movement of people around the bus is high, thus multiplying the possibilities of an accident, as the driver cannot be certain as to the presence of obstacles or people in the immediate vicinity of the bus. Moreover, people that travel standing up may fall and get hurt, particularly the older people. The objective of the SAFEBUS project is to minimise accidents inside or around city buses, as well as the related injuries. By developing new technological breakthroughs and ergonomic solutions, the project seeks to directly improve quality of life for people.
Phase 1 "Analysis of requirements and needs" involved a study of accidents on buses, both outside the vehicle, including accidents with knock-downs in areas where passengers get on/off (stops), and inside it, analysing the possibility of a passenger having an accident inside the bus due to falls, impacts or blows.

The activity in this phase focused on three major areas: documentary revision, user discussion groups and field studies.

1. Documentary revision
This activity focused on an analysis of previous studies related to accidents without a collision in city buses, as well as the data bases of accidents from the main insurers in Spain. The information collected was also used to draw up the script of the discussion group and the observation data sheets used in the observational studies.

This study, together with the documentary revision, allowed us to characterise the problem and identify the requirements and needs of the systems to be developed in both environments (inside and outside the vehicle) to help prevent injuries to bus users by means of the design of new active and passive safety concepts.

2. Discussion groups
The discussion group is a technique that makes it possible to address a series of topics broadly, and compare the different perspectives and points of view. The ultimate objective of the discussion session carried out in Valencia was to detect the necessary improvements on the design of the inside of the bus to make it safer. A series of specific objectives was established:

-- To identify key, higher-risk moments, and what elements are involved.

-- To ascertain what incidents occur at any moment and what design aspects or elements are related to them.

-- To define possible solutions to problems and determine the profile of higher-risk users.

As a result, the key moments in the use of the bus in terms of safety were obtained, taking into account the risk of the occurrence of incidents, and solutions were sought depending on the problem (Table 1).

3. Observational study
A pilot test was carried out before the observational study to validate the observation data sheets. To achieve the specific objectives set in phase 1, two observational studies were performed on a representative sample of the bus lines (inner city, old district, radial, circular) in the cities of Valencia (EMT buses: 6, 9, 18, 41, 62 and 64 lines) and Zaragoza (Tuzsa buses: Cl 1, Cl2, 53, 31, 33 and 25 lines). The incidents that passengers had while using the bus were recorded, and were documented to characterise and subsequently relate the incidents to the different design elements of the bus. The observations were made over a week, both inside and outside the buses (EMT Valencia and Tuzsa Zaragoza), recording whether there was any incident when the passengers got on, got off, walked along the corridor, paid, were looking for a seat, got up, were sitting and/or were standing.
Moreover, in the study in Zaragoza a measuring system (VC3000) was installed in the buses of each line with the capacity to record speed, acceleration, braking distance and equivalent coefficient of friction during braking. The vehicle’s longitudinal and transversal accelerations were measured (Figures 4a and 4b), making it possible to identify moments when the user might fall (acceleration threshold: 0.15 g) and relate them to any incidents that might occur on the bus.

**Conclusions**

The study showed that the frequency of incidents in the metropolitan network of buses in Zaragoza, as in Valencia, is very low. Most of the incidents that occur are caused by accelerations or brusque braking of the bus.

In the case of on-board observations, there was only an incident in 1% of the cases (23 of 2280), while outside the vehicles there was an incident in 0.73% of cases of people getting off and 0.23% getting on. While the sample recorded is not fully representative of the total amount of passengers that use the bus network daily, it allowed us to obtain relevant information in order to move forward in the development of the project.

The incidents recorded, both on board and off the vehicle, were minor. There were no major injuries or wounds. Of these incidents, several may be related directly to design elements, such as corridor width, space on the seat, height of the step, grips, door closing, etc.

The frequency of the incidents made it possible to determine the most conflictive locations in the inner cabin (entrance/exit of the bus, access to the seats, main corridor) that will be studied in the following phases for the development of new safety systems.

The results show that the people most likely to be involved in an incident are the older persons. However, most older people use the reserved seats and are very careful; in fact
they wait until the bus has braked fully to move around and get off the bus.

**Subsequent Phases**

The following phases of the project will involve the development of driving aid systems for the detection of people and obstacles at low speeds, and the spaces will be defined inside the bus, introducing new elements that help to prevent falls in vulnerable users. In turn, new passive safety systems will be developed for the inside of the vehicles, particularly adapted to user ergonomics. For this purpose, new tests and simulation protocols will be established that make it possible to evaluate the efficacy of the new safety designs and systems developed, representing, as best as possible, the conditions in which the accidents and injuries take place. The project will culminate with the integration of the different safety systems in a Castrosua test bus.

**Acknowledgements**

Our acknowledgement to the EMT Valencia and TUZSA companies for their collaboration in the observational study.

Project co-funded by the Ministry of Economy and Competitiveness through the INNPACTO 2011 programme in the instrumental line of articulation and internationalisation of the system, framed within the National Scientific Research, Development and Technological Innovation Plan 2008-2011, and by the European Union through the ERDF funds.

The project features, besides the IBV, with the participation of Castrosua, Centro Zaragoza, Cognitive Robots and the Polytechnic University of Valencia through the Instituto de Diseño y Fabricación.
Goals on artificial turf: more lasting and sustainable

Mercedes Sanchis Almenara, David Rosa Máñez, Laura Magraner Llavador, María Teresa Pellicer Chenoll, Ana Cruz García Belenguer, Alfredo Ballester Fernández, Carlos Chirivella Moreno, Luis Garcés Pérez

INTRODUCTION

Suitable maintenance of artificial turf football fields is known to increase the lifetime of this type of sport surface, while maintaining suitable properties for the safe practice of sports. However, the information currently available to the managers of installations and the people in charge of maintenance is not sufficient to perform suitable maintenance just when it is needed. This leads to a reduction in the service life of this type of surfaces that are in optimal conditions for use.

Moreover, when it is no longer possible to recover the properties of the playing field to guarantee safe sports, it must be removed, generating 100 tons of non-hazardous waste, which are currently transported directly to controlled landfills. However, some parts can be reused in the installation of a new artificial turf football field, and others may be recycled, whereas other products can be manufactured with the polymeric materials yielded by the aforementioned recycling.

This article delivers the results obtained from the ECOTURF project, which ranges from improving the management and maintenance of artificial turf football fields to put off the moment of removal as far as possible, to solutions for the on-site reuse of the material and the recycling of material that cannot be reused directly.

DEVELOPMENT

The project was performed in three different phases: optimisation of the management and maintenance of artificial turf football fields, reuse of materials in the installation of a new artificial turf football fields and recycling of materials that are not directly reusable. The results obtained in each one of them are detailed below.

1. Optimisation of the management and maintenance of artificial turf football fields. The objective of this phase is to extend the life cycle of artificial turf football fields in safe conditions of use as much as possible. To do so, a web application was developed to provide support to installation technicians, both in the management of artificial turf football fields and for suitable maintenance, depending on the use and the condition of the field.

After registering in the application (http://comunidad.ibv.org/cesped) (Figure 1), users have a management system that allows them to book an installation, indicating the use to be made of it (Figure 2), and this information will appear in a totally accessible calendar for the manager. In this calendar, the tool will include maintenance operations that should be conducted on the field, taking into account both the use made of it and its structure (Figure 3).
Moreover, the tool provides approximate information on the properties of artificial turf fields based on user opinions. The correlation between both (the opinion of players/properties of the playing surface measured by means of regulatory tests) was obtained by means of mechanical tests and subjective evaluation (surveys on players) on a large number of artificial turf fields with different structures (different fibre lengths, different filling material, etc.); these assessments were made before and after maintenance operations to ascertain the effect of these operations on mechanical properties and on the opinion of the players in the fields analysed.

The correlation between the results of the surveys on players and the properties measured by means of mechanical tests makes it possible to get information such as that which is displayed in figure 4, with which installation technicians can have an approximate idea of the state of their fields in terms of the minimum requirements laid down by the European legislation (EN 15330-1 in its specific section on football) or FIFA (in its FIFA Quality Concept manual) for each one of the properties evaluated.

Moreover, the users of this application can obtain a results report specifying the opinion of the users and the state of the field with regard to the applicable legislation, as well as recommendations for specific maintenance actions to be carried out.

2. Reuse of the material in the installation of a new artificial turf field. The second objective of the project consists of developing a machine that can separate, in the actual installation, the different filling materials of the “carpet” (the part of the artificial turf made of textile, over which green fibres are woven to make it look like natural turf). Performing this separation on site brings savings in fuels and in the emission of greenhouse effect gases involved in the transport of approximately 100 tons of material to a controlled landfill. The filling materials are separated by sizes in big bags (Figure 5) that will permit easy handling for the installation of a new artificial turf field.

3. Recycling of materials that cannot be reused directly. The artificial turf carpet is the part that is subject to

Figure 1. Home of the management tool for artificial turf fields.

Figure 2. Edition of uses of artificial turf fields.

Figure 3. Calendar of uses of the field and recommendable maintenance.

Figure 4. Graphic representation of the properties of the artificial turf fields obtained from the surveys.
The greatest deterioration in this type of products, hence its reuse in the installation of a new artificial turf football field is not viable. Recycling was considered from two points of view:
- Direct reuse in alternative uses (for example in paintball installations) (Figure 6).
- The in-plant recycling of the different materials of the carpet for use in the manufacture of new products. A system of separation by cryogenia was set up for this purpose. In it, the differences in the cryogenisation temperature of the materials that make up the carpet of artificial turf permits separation. The purity of the material separated is sufficient for use as new material in the manufacture of new products (for example for the obtainment of polymeric materials by extrusion).

**CONCLUSIONS**

The main conclusions obtained from the work performed in the ECOTURF project are:
- Suitable maintenance makes it possible to prolong the life cycle of artificial turf football fields and in optimal conditions of use. Therefore, the use of the application developed that allows installation technicians to know the operations to be performed according to the use and the typologies of field will lead to an increase in fields' life cycle.
- The reuse of filling material in the installation of a new artificial turf football field brings a considerable reduction in the waste deposited in landfills. Moreover, the fact that the separation of these materials is performed on site will lead to a reduction in the consumption of fuel and in the emission of greenhouse effect gases.
- The carpet materials can be recycled by cryogenisation processes, yielding materials with sufficient purity to be reused directly in the manufacture of new polymeric products.

**Acknowledgements**

This work was possible thanks to funding from the CIP ECO-INNOVATION Pilot and market replication projects programme (ECO/08/239059/SI2.53788).
Point-of-sale shoe customisation

Sandra Alemany Mut1, Sara Gil Mora1, Ramón Moraga Maestre3, Enric Medina Ripoll1, Juan Carlos González Garcia2, Jaime Díaz Pineda1, Jaime Prat Pastor1,2, Clara Solves Camallonga1, José Olaso Melis1

1 Instituto de Biomecánica de Valencia
2 Grupo de Tecnología Sanitaria del IBV, CIBER de Bioingeniería, Biomateriales y Nanomedicina (CIBER-BBN)

INTRODUCTION

Funded by the 7th Framework Programme of the European Union, Fit4U (Framework of Integrated Technologies for User Centred Products), it is a collaboration-driven research project whose objective is to improve the competitiveness of European footwear and accessory manufacturing companies through the development of new technologies and solutions that make it possible to offer consumers products adapted to their needs. The project addresses new developments to personalise functional aspects of sports and occupational footwear in all phases: marketing, design, production and logistics.

The functional customisation of footwear is determined by the setting it is used in (type of floor or ground, terrain, weather conditions, etc.) and the specific characteristics of each user: foot morphology and biomechanical profile. However, current technology for the characterisation of the user’s biomechanical profile is mostly laboratory-based and is not adapted for in-store use. The complete functional adaptation of footwear is still done in a very artisanal way and is consequently very costly. Moreover, new materials that cover users’ ergonomic and functional requirements are called for. These challenges have been addressed in the main research and development lines of the FIT4U project to personalise sports and occupational footwear. The most important results of the project are grouped as follows:

- New technologies to generate the user’s morphological and biomechanical virtual profile.
- Innovative and integrated 3D design tools for the customisation of footwear based on design expertise and rules that allow us to adapt the product’s characteristics to user needs and preferences.
- New materials with better functional and safety characteristics for products with high performance requirements such as sports and occupational footwear.
- New technologies for the rapid production of lasts, templates and soles, and new production management tools.

The Instituto de Biomecánica’s (IBV) contribution to the project focused on the user study. On the one hand, the functional, morphological, biomechanical and thermal specifications of occupational and sports footwear were defined to adapt to user needs, and on the other, new technologies were developed to characterise the user and transfer these parameters to the actual design of the footwear. Two of the project outcomes are presented below, which herald a major advance...
in the selection and personalisation of footwear, resulting from the research conducted by the IBV:

- An in-store biomechanical characterisation system for running which makes it possible to select sports footwear, with user-adapted movement control and impact absorption.

- A methodology for the personalisation or selection of footwear adapted to the 3D anthropometry of the user's feet.

**Technology for measuring the runner's biomechanical profile in the store**

The adaptation of sports footwear, particularly running shoes, to the user's biomechanical profile, is fundamental in the prevention of injuries and pain, improves performance and increases comfort. For this reason, most sports footwear brands offer products with different characteristics of movement control and impact absorption according to each runner's needs. These specific adaptations of footwear are becoming increasingly more appreciated by users. However, the main difficulty in making a correct selection is associated with the precise characterisation of the biomechanical profile that defines each user's needs.

The Fit4U project allowed IBV to develop a system for measuring the runner's biomechanical profile, simply and objectively, at the point of sale. The biomechanical profile defined by the IBV includes the characterisation of the pattern of movements of the foot/ankle (Figure 2), following the biomechanical model proposed by the International...
Society of Biomechanics (ISB), and the characterisation of the impacts transmitted to the body during running (Figure 3). This system is comprised of inertia sensors that make it possible to measure the relative movement between the rearfoot and the leg to analyse, among other aspects, the user’s degree of pronation/supination while they are running, and accelerometers, which measure the transmission of the impact of running to the tibia (Figure 4). The information recorded is transmitted in real time by means of a Bluetooth connection to a computer, tablet or smartphone for processing, and the user is classified according to the degree of pronation and natural impact absorption capacity.

The demonstration phase of the project included a study in a real-life situation to analyse the biomechanical suitability of new mountain footwear prototypes developed by the SCARPA company. These prototypes feature the new materials and components developed in the Fit4U project (Figure 5).
> Customisation of footwear lasts based on the anthropometric profile of the user's foot

There are numerous 3D capture systems that can characterise the shape and dimensions of the user's foot in order to determine size or make adaptations to the footwear to improve fit. However, the transfer of anthropometric dimensions to footwear design is performed manually, since although computer-assisted design tools are used, it is usually an expert that modifies the last's adjustment areas on the basis of their experience and criteria.

The IBV's activity in footwear fitting and personalisation has focused on the development of a methodology that makes it possible to automatically calculate the last adapted to the shape of the user's foot by applying ergonomic design criteria. This methodology includes the know-how generated by the IBV over years of studying footwear fitting, and comprises:

--- Analysis by means of geometric morphometric techniques of 3D foot data bases of the adult population generated by the IBV to characterise the variability of shape and size of the population's feet.

--- The same techniques were used to analyse the variability of the shape and size of footwear lasts and the geometric relationship with foot morphology to achieve a suitable fit (Figure 6).

--- The study of the dynamic interaction between foot and footwear by means of pressure sensors made it possible to relate how aspects such as stiffness of the footwear, the elasticity of the cutting material and the type of activity affect fit.

--- The characterisation of the elasticity of the cutting material (Figure 7) made it possible to establish tolerance margins in the design of customised lasts, considering the level of adaptability the cutting material will have during use.

This tool for the automatic calculation of the last geometry personalises on the basis of the critical sections for fit and can be integrated with computer-assisted design programmes through standard file exchange formats such as dxf.

> Conclusions

The FIT4U project, in which the Instituto de Biomecánica (IBV) has provided its experience in the study of users and their integration in the different phases of the personalisation process, will promote personalisation and will help in the selection of footwear at the point of sale through the contribution of technological innovations that will make these services a reality.
The characteristics of users of **trekking**, **running** and safety shoes were studied, making it possible to establish specifications for the development of new materials and components for these products.

One major problem faced by runners when they buy shoes lies in selecting the ones that best match their running style. In fact, specialised user forums contain multiple proposals for determining the type of foot and, with this information, the way a person runs. However, these methods do not provide information on absorption capacity and running dynamics. The IBV has developed equipment that makes it possible to objectively measure the runner’s biomechanical characteristics at the point of sale to subsequently relate them to footwear design aspects, making it possible to recommend the best trainers for a given runner.

As for the customisation of shoe fit, one of the current barriers is that adaptations of the last to the user’s foot are performed manually by highly-trained personnel. In this project, the IBV developed a methodology that makes it possible to automate the customisation of lasts based on the foot’s 3D information, leveraging know-how on the foot-footwear dynamic interaction and the effect of the elastic characteristics of the cutting material.

Further information: [www.fit4u.eu](http://www.fit4u.eu)

**ACKNOWLEDGEMENTS**

To the European Commission for its contribution to this collaboration project, which was co-funded through the 7th Framework Programme (NMP2-SE-2009-229336).

To the SCARPA, VIBRAM, PAREDES and BASE-Protection companies that participated in the product validation.
Making classic footwear more flexible

Sergio A. Puigcerver Palau, Arturo Gómez Pellín, Clara Solves Camallonga, Enrique Medina Ripoll, Juan Carlos González García, Sara Gil Mora, Roberto Ferrandis Ferrer, Pedro Huertas Leyva

INSTITUTO DE BIOMECÁNICA DE VALÈNCIA

INTRODUCTION

The flexibility of footwear is related to the strength needed to bend the shoe at the widest part of the forefoot. Flexibility largely determines comfort in walking. A rather inflexible shoe increases the energy needed to bend the foot, and consequently increases fatigue during walking; walking becomes more difficult, causing an increase in plantar pressure on the forefoot, augmenting the likelihood of friction marks appearing on the heel. This makes it advisable to use shoes that guarantee the flexion of the forefoot, including flexion systems both in the sole and in the cutting material to follow the foot’s natural movement. The SEMIC S.A. company, assessed by the Instituto de Biomecánica (IBV), has developed a new system to promote footwear flexion for men’s and women’s shoes. The system has been optimised and validated thanks to the collaboration between both organisations.

The new system comprises a series of notches that have been adapted to the foot’s natural axis of flexion to improve the flexibility of the footwear when walking or engaging in daily activity. Moreover, tensors perpendicular to the flexion lines have been included, intended to completely recover the original shape once the maximum flexion point has been surpassed (Figure 1). This stops the footwear from becoming progressively deformed through use, particularly in the forefoot, due to the continuous flexion caused in this area on walking.

The flexibility of footwear largely determines comfort while walking. Barely flexible footwear increases fatigue, makes walking more difficult and the probability of friction on the heels is higher. These are the reasons that led the company from Navarre, SEMIC, assessed by the Instituto de Biomecánica (IBV), to develop an innovative system in the sole that makes even the most classic footwear more flexible. This technology can be fitted in any type of footwear, such as ladies’, gents’, children’s and occupational and sports shoes, and even in the most classic type, which normally uses leather soles. The new flexion system developed increases footwear comfort by 25% and the intention to purchase the product by 40%.

Figure 1. Flexion system developed.
The system includes two axes of flexion with an asymmetric design. One of them, the one furthest from the tip of the shoe, is used to enhance dorsal flexion of the forefoot. The one closest to the tip of the shoe is designed to promote toe springiness. These two axes are more separated on the outside of the foot than on the inside, to promote progressive flexibility during walking. In both cases, the footwear must have sufficient flexibility, observing the natural movement of the foot and making sure that the force of impulse faces in the direction of movement (Figure 2). Similarly, this system enhances the grip of the shoe to the ground on walking, particularly in footwear with a leather sole, reducing the risk of falls and injuries, although it is also applicable to rubber, TPU, TR or injected EVA soles.

**Development**

To generate the design of the region of maximum flexibility at the forefoot, the IBV’s data bases containing feet anthropometric measurements from the male and female population were used, determining the position of both axes of flexion, orientation, variability between users, as well as the variation in the foot’s static geometry on walking. The flexion region was designed to be shorter in the inner part of the sole than the outer area, providing progressive flexibility during movement: the sole’s flexion line progresses from the bottom to the top, so that it does so faster in the outer part of the footwear, thus imitating and promoting natural foot movement (Figure 3).

The new flexion system developed has been validated by means of three complementary tests: 1) Evaluation of the footwear’s level of flexibility with the IBV test machine; 2) Influence of footwear on the foot’s natural movement; 3) Evaluation of comfort and satisfaction with the new system.

The first test compared, with the IBV’s specific test machine, the flexibility provided in the forefoot of several footwear models of different ranges, with and without the new flexion system. All the models tested that include the new flexion system provide greater flexibility than that which is recorded in the models that do not include it, and is almost double in the case of casual footwear, and three times more flexible in the case of gentlemen’s dress footwear (Table 1).

Table 1. Percentage of improvement in the flexibility of the models evaluated thanks to the use of the new flexion system.

<table>
<thead>
<tr>
<th>Model Type</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gentlemen’s dress footwear</td>
<td>229</td>
</tr>
<tr>
<td>Gentlemen’s casual footwear</td>
<td>95</td>
</tr>
<tr>
<td>Women’s casual footwear</td>
<td>87</td>
</tr>
</tbody>
</table>

To evaluate the influence of footwear on the foot’s natural movement and to check that both axes of flexion proposed are working correctly, an analysis was performed with people using photogrammetry technology that analyses movement on walking (Figure 4).
The results demonstrated that the flexion system works properly, providing a level of flexibility in use of up to two times greater than standard footwear (Figure 5).

A subjective analysis of the perception of a set of people that have tried the system was performed in order to determine the level of comfort of the system and intention to purchase. All the people that participated in the study regard the footwear with the new system as more flexible, achieving a suitable level of flexibility. The comfort provided by footwear featuring the new system was rated as much better than the footwear that did not include it (25% increase in comfort). Regarding intention to purchase, including the new flexion system entailed an increase of almost 40% in the percentage of people willing to buy the model evaluated.

CONCLUSIONS

Following the validation carried out by the Instituto de Biomecánica (IBV), it may be asserted that the new flexion system developed together with the SEMIC company considerably improves the flexion of the forefoot on walking, and therefore notably increases the level of comfort perceived by users, preserving the foot’s natural movements during walking and avoiding the permanent deformation of footwear in the forefoot area after use. In addition, the flexion system increases the intention to purchase the product.

ACKNOWLEDGEMENTS

To the company from Navarre, SEMIC, S.A.

In this project the company enjoyed the support of the Centre for Industrial Technological Development (CDTI) through its Programme for Research and Development Projects (RDP).
Who says that video games are not for older persons?

Andrés Soler Valero¹, Estela Suárez García¹, Amparo López Vicente¹, Paloma Peris Perez¹, Rakel Poveda Puente¹, Javier Ferris Oñate¹, Javier Sánchez Lacuesta¹,², Clara Bollain Pastor¹, Laura Martínez Gómez¹, Rocío Zaragoza Martín³, Stefan Beyer⁴

¹ Instituto de Biomecánica de Valencia
² Grupo de Tecnología Sanitaria del IBV, CIBER de Bioingeniería, Biomateriales y Nanomedicina (CIBER-BBN)
³ Instituto Tecnológico del Juguete (AIJU)
⁴ Instituto Tecnológico de Informática (ITI)

INTRODUCTION

Although video games have traditionally targeted young people and children, numerous studies conducted in recent years have demonstrated the potential benefits for older persons, both in the sphere of prevention and in physical or cognitive therapy. The popularisation of the video console and the aging of the first generations that enjoyed these products shows that older persons will be potential users of this type of leisure.

In recent years, some video games targeting this group have arrived on the market, mostly from the United States and Japan. However, their presence at points of sales is still very scant. Older people, their families, and experts in the aging process are calling for new initiatives that will make it possible to fully improve the quality of life of this group by optimising their use of their free time with quality proposals (recreational, preventive and therapeutic).

Video games for older persons have many and wide-ranging benefits. They improve motor skills, reflexes and rapid response, as well as visual perception, eye-hand coordination and the perception of space. Besides improving the cognitive capacities of older persons, and strengthening and improving their daily life activities, video games are also being used for the treatment and rehabilitation of patients and the prevention of falls.

The SENIORPLAY project, with a duration of two years, was conceived to address these demands. Its objective is to establish the bases for the development of video games with high therapeutic and preventive value that also fulfil the specific usability requirements of older persons. The project features the participation of three technological centres from the Community of Valencia: the Instituto Tecnológico del Juguete (AIJU), the Instituto de Biomecánica de Valencia (IBV) and the Instituto Tecnológico de Informática (ITI).

DEVELOPMENT

The first year of the SENIORPLAY project involved phases targeting the generation of knowledge, analysis with experts and fine-tuning of the methodology for rating video games.

Phase 1. State of the art and analysis of the initial situation

This phase involved an exhaustive study of the most relevant research related to technological leisure and interventions in older persons through video games, as well as the application of video games to improve the quality of life of older persons. This revision made it...
possible to ascertain the potential of video games and the effects they have on older persons.

This phase also involved the implementation of a market study on products related to video games, consoles, controllers and currently available related devices and technologies, rating their characteristics, advantages and drawbacks.

Finally, with the information compiled in this phase, and after an analysis by the experts, a list of products was prepared on the basis of selection criteria (possibility as an intervention tool, gaming dynamic, subjects, etc.), for them to be evaluated and assessed in subsequent phases with older persons and experts.

Phase 2. Needs and requirements detection

The objective of this phase was to ascertain priority lines of action to improve the quality of life of older persons and collect and analyse the appraisals of the experts in aging about the applicability of video games in interventions with older persons.

In order to achieve the objectives, a study was performed with experts in aging (doctors from homes, physiotherapists, psychologists, social workers and sociocultural animators). The study was conducted with a methodological approach based on people-oriented design, with the participation of professionals in topics related to seniors through the use of different techniques (thinking aloud, observation log, repertory grid (RGT), discussion groups) over two working days (held in Valencia and Alicante) with several evaluation sessions.

The specific objectives addressed at these sessions were:
1. To identify priority intervention areas with this type of products.
2. To identify the subjects of greatest interest.
3. To identify the most suitable types of games for older persons.
4. To detail the accessibility and usability requirements to be taken into account during design and development.
5. To identify the most effective interfaces and monitoring systems in the therapeutic and preventive context.
6. To assess the suitability of existing products on the market.

Following this line, the conferences with experts were split into four parts:
-- Presentation of the project, objectives of the conference and participants.
-- Session-play (Figure 1). In this part, the participants tried different video games and consoles in pairs, identifying an initial list of problems of use, requirements and proposals for improvement to be added for use by older people. They then went on to evaluate the consoles and video games (Figure 2a y 2b).

Figure 1. Evaluation sessions during the conferences held at IBV and AIJU.

Figure 2a. Results. Fulfillment of criteria according to the platform used (1-5).

Figure 2b. Results. Fulfillment of criteria according to the platform used (1-5).
- Debate. Three debating tables were formed, according to professional profiles, to develop panels of experts with the following subjects:
  - Areas of intervention through video games.
  - Subjects and types of video games of interest for older persons.
  - Usability requirements, interfaces and monitoring.
- Conclusions. Finally, one spokesperson for each debating group reported their conclusions to the whole group on each one of the subjects treated. These presentations were followed by a session with inputs pooling the different views, prioritising the most relevant aspects.

This study made it possible to identify needs, demands and expectations with regard to the different areas of intervention with video games, as well as the subjects of interest and the requirements to be considered in the development of video games for older persons.

PHASE 3: ERGONOMIC AND USABILITY ANALYSIS

This phase defined the techniques for assessing, objectively, the emotional response and the user's behaviour as they interact with "video games" and the protocols for the usability study by means of the use of biomedical techniques.

Three sources of information were taken into account in defining the protocol for the implementation of the usability tests for the assessment of video games with users:

1. Subjective user information following use of the interface. A questionnaire was designed asking about general aspects, such as perception of difficulty of use, and more specific aspects such as modifications they would make to the console/video game interface.

2. Subjective information from the researcher obtained by observing the user. Data sheets were defined to help in collecting the general observations, referring to the doubts or wrong decisions in the use of the console/video game interface.

3. Objective information obtained during the use of the interface. The analysis of physiological signals (GSR, EMG, HRV) was used, together with the usual parameters, such as measuring the time needed to perform a series of tasks, the number of mistakes made or the number of steps taken to perform the task.

Work is still ongoing in determining the influence of physiological parameters on usability, analysing the interference of the recreational part of the video game on emotions, the effect of abrupt gestures/movements on the recording of signals and the identification of the changes that take place in the physiological signals they are associated with.

This project applies the SIMPLIT methodology for the evaluation of the console/video game. SIMPLIT (http://www.simplit.es) is an initiative of the Instituto de Biomecánica and the Unión Democrática de Pensionistas y Jubilados de España (UDP), with the support of AENOR, which guarantees that a product is easy to use by all people after a process of assessment and evaluation with the active intervention of older persons.

CONCLUSIONS

After one year of the SENIORPLAY project, the phases of identification of the requirements and needs of video games/platform have been successfully completed, laying the foundations for the generation of design criteria and recommendations which, on completion of the project, will be part of the guide for video game developers.

The adaptation of video games to older persons entails improving the accessibility and usability of games, adapting to the subjects of interest for older persons and maintaining and increasing the recreational aspects while also limiting competitiveness in gaming.

This guide will collect key aspects as priority areas of intervention with this type of products, interfaces and more effective monitoring systems in the therapeutic and preventive context, subjects of greatest interest, most suitable types of games for older persons, or accessibility requirements to be taken into account for design and development. The ultimate goal is to determine the key aspects for producing video games that will contribute to improving the quality of life of older persons. This will make it possible to develop video games conceived particularly as a support tool for professionals engaged in caring for seniors or the older persons.

ACKNOWLEDGEMENTS

We would like to thank the experts of the Nuestra Señora del Carmen Health and Social Centre, the Instituto Geriátrico Valenciano, the SARquavitae Ciudad de las Artes home, the Tercera Edad Velluters home, Hermanas Hospitalarias, as well as several CEAM centres of City Council of Valencia and of Sagunto, and the Novaire group, for their participation in the work sessions held in the Instituto de Biomecánica and in the AIJU.

This project was co-funded by Instituto de la Mediana y Pequeña Industria Valenciana (IMPIVA) and the European Regional Development Fund (ERDF), through the Projects in Collaboration Programme, which is part of the programme of support to the Technological Institutes of the IMPIVA network for 2011.
The Aquarius amphibious marine wheelchair, back on the beach

Ricard Barberà i Guillem1, Juan Gómez Herrero1, Ignacio Bermejo Bosch1,2, José Navarro García1, Fernando Sánchez de Lara3, Sergio Puigcerver Palau1, Rubén Lahuerta Martínez1, Ramón Moraga Mestre1

1 INSTITUTO DE BIOMECÁNICA DE VALENCIA  
2 GRUPO DE TECNOLOGÍA SANITARIA DEL IBV, CIBER DE BIOINGENIERÍA, BIOMATERIALES Y NANOMEDICINA (CIBER-BBN)  
3 WINNCARE by VIRMEDIC

INTRODUCTION

In the year 2000, the Instituto de Biomecánica (IBV), together with WINNCARE by VIRMEDIC, developed an amphibious wheelchair whose purpose was to facilitate access to the beach and to sea-bathing for people with reduced mobility. A large number of disabled, their relatives and beach monitors participated. Ten years after that, on the basis of the experience gleaned in the use of the product on the beach, the need to review the design was addressed, focusing on the following aspects: (1) improve on-sand manoeuvrability and (2) improve the look of the product, making the chair more appealing and lighter.

METHODOLOGY

The project was structured in three phases: (1) identification of improvements and design proposals, (2) prototype development and (3) validation.

1. Identification of improvements and design proposals

The identification of improvements was based on the experience of the previous years of marketing of the product. Both users and the beach monitors agreed on the main aspect to be improved: manoeuvrability on the sand of the beach, while also maintaining equivalent floatability conditions in the water.

The following chair functions were identified to facilitate the development of new design items to improve this initial situation: (a) getting on and off the chair, (b) entering and exiting the water, (c) moving in a straight line on the sand, (d) turning on the sand and (e) floating on the water.

Before the implementation of the design proposals, existing solutions on the market to facilitate access to the beach and bathing in the sea were reviewed, as were the most important structural elements and parts (wheels, floaters, structure).

In order to guarantee the maintenance of floatability conditions, a floatability model was developed that made it possible to simulate the possible effect of different design modifications on the final floatability and stability of the chair in the water.

This phase ended with the prioritisation of the improvement proposals and the development of different sketches of the design concepts. The most noteworthy ones were the simplification of the chair structure, the elimination of original elements (such as the original rear floats), as well as the change of the wheel rotation and distribution system. In the new model the turning wheels were located at the front, whereas the wider wheels remained at the back.
Figures 1 and 2 show different sketches of the improvement proposals on which the researchers of the IBV and the WINNCARE by VIRMEDIC production team were working.

2. Development of improvements

The conceptual designs were used to develop a **functional prototype** for testing the different configurations on the

- Separate sub-assemblies (Wheel chair and seat)
- Avoid machined parts, joins and welds
- Facilitates part handling and assembly
- Modular
- Can be transported separately
- Logistics

![Figure 1. Sketches to simplify the structure 1.](image1)

![Figure 2. Sketches to simplify the structure 2.](image2)
sand and in the water at the beach (Figure 3). The process was developed iteratively, initially selecting the configuration that worked best on the beach, and adjusting the design parameters of this same configuration in the following tests. This permitted the development of an amphibious chair with optimal on-sand behaviour (manoeuvrability) and in the water (floatability, stability, entering and exiting the chair for free swimming).

On the basis of the information collected during the project and the concept tests performed on the sand and in the water, sufficient information was collected to develop the definitive designs of the AQUARIUS chair (Figure 4).

3. Tests
The objective of this phase was to guarantee that the enhancements implemented in the amphibious chair improved functionality and did not alter other characteristics such as safety for the patient and caregiver. To this end, manoeuvrability tests were performed on the beach, and tests in the IBV laboratory. As has been commented, the objective of the manoeuvrability tests was to guarantee that characteristics on sand and in water improved. The tests in the IBV laboratory were intended to verify fulfilment of wheelchair regulations. While some sections are not directly applicable, others related to material resistance (impact, fatigue) or entrapments are. Besides in-house procedures, parts of the UNE-EN 12182 Standard, related to technical aids, the UNE-EN 12186 Standard on manual wheelchairs and the ISO 7176, which defines testing procedures for wheelchairs (Figure 5), were applied.

**Results and Conclusions**
The result of this project is a new design of the Aquarius chair with better manoeuvrability on the beach and a revamped and more appealing design. During the implementation, the
complete design and development process was completed, based on the experience and assessment of the product users over these last few years, and thanks to a flexible and direct collaboration between the manufacturer (WINNCARE by VIRMEDIC) and the developers (IBV).

Figure 5. Detail of the tests: a) Lateral stability; b) Armrest traction.

ACKNOWLEDGEMENTS

This project was conducted within the framework of the Call for Aid of the II Plan of Competitiveness of the Valencian Company (PCEV) for the year 2010, in Strand 3: Assessment in Innovation and Modality: 3.2. Rendering of services in innovation through design. Project co-funded by the ERDF Funds in the ERDF Operational Programme 2007-2013 for Valencian Community.
Assessing hand capacity objectively

José Montero Vilela1, José María Baydal Bertomeu1, David Garrido Jaén1, Ignacio Bermejo Bosch1,2, Álvaro Page del Pozo1,2,3, Rosa Porcar Seder1, Inigo Morales Martin1,2, Ricard Barberà i Guillem1
1 Instituto de Biomecánica de Valencia
2 Grupo de Tecnología Sanitaria del IBV, CIBER de Bioingeniería, Biomateriales y Nanomedicina (CIBER-BBN)
3 Universitat Politècnica de València

Rationale for the development of the NedMano/IBV application

The hand is the organ that allows us to physically handle the medium since with it we grip and move objects, exercise force, ascertain the texture and temperature of surfaces we touch, etc. In fact, by combining these functions we manage to carry out the multiple actions that are necessary to do our work, sports or basic everyday activities such as eating, dressing or washing.

The most common lesions that affect the hand may be originated by neuromuscular or traumatic conditions. The former particularly include central nervous system deficits such as stroke or cerebrovascular diseases, and deficits of the peripheral nervous system such as carpal tunnel syndrome – due to the entrapment of the median nerve at the wrist. The conditions most commonly caused by trauma are fractures of the forearm or wrist that may lead to a loss of strength through pain or affection of the peripheral nerves. Unfortunately, this type of alteration affects a broad range of the population and, as is predictable, entails a drastic reduction in personal autonomy.

Following the appearance of a deficit in the hand, it is indispensable to ascertain its functional capacity. Ascertaining this functional capacity allows us to suitably define the necessary therapy for recovery, ascertain whether a worker should take sick leave or return to work, and even issue a disability proposal befitting the person’s real limitation.

Usually, the functional assessment of the hand is performed through the evaluation of the force a person can exercise. This evaluation can be carried out manually or with instruments. The manual exploration consists of a subjective assessment by the professional of the patient’s ability to apply pressure with the hand. The exploration with instruments was conceived to reduce subjectivity in assessment and consists of recording the hand’s strength with a dynamometer. However, with these instruments it is difficult to make a suitable assessment, since the reference values that are useful to Spanish health professionals are unknown. This is because existing databases have been constructed with non-Spanish populations, based on different protocols and instruments regarding which there is insufficient information to be able to reproduce them suitably.

In view of this situation, the Instituto de Biomecánica (IBV) addressed the development of the new application: NedMano/IBV, capable of evaluating the hand’s functional ability objectively, rapidly and simply based on the maximum strength applied and the fatigue produced in different functional gestures. This application is integrated...
within the range of applications for the functional assessment of the IBV.

**Development of the NedMano/IBV application**

The development of the NedMano/IBV application is the result of research that began in 2009. The following activities were performed during the aforementioned study.

-- Phase 1. The measuring protocols and the target variables for the assessment were analysed and defined.

-- Phase 2. A database of healthy subjects was generated to ascertain whether the results of a specific subject are within what may be regarded as normal for their age, gender and dominance.

-- Phase 3. A user-friendly software tool was developed, capable of managing all the input and output information automatically.

More specifically, in Phase 1, the measuring protocol was defined according to the indications of the American Society of Hand Therapists (ASHT). This society indicates both the measuring position and the strength recording interval necessary for the subjects’ muscle recovery (Figure 1). This protocol is based on the measurement of isometric forces using the NedVEP/IBV dynamometer. Moreover, two stages were defined in the strength measurement recording process. The objective of the first step is to record the maximum strength of each one of the hands in the gestures of gripping, distal pinch and lateral pinch. On the other hand, the objective of the second stage is to measure the fatigue of each hand in the grip gesture. Three repetitions are performed with the dominant hand and a further three with the other hand to measure maximum strength. To assess fatigue, a sequence is used, beginning with a reading at 100% of the maximum strength value, a second at 25%, a third at 75% and the last at 50%. In this case, the measurements are taken by switching between right and left hand to permit sufficient recovery of the muscle groups.

![Figure 1](image)
In the course of Phase 2, measurements were performed on healthy subjects in the functional assessment laboratory of the IBV to generate a database of healthy subjects. The database of the NedMano/IBV system has a sample of 110 healthy Spanish subjects (54 men and 56 women) with an age range between 20 and 69 years. The subjects included in the sample reported no pain or neurological or musculoskeletal problems of the hand or upper limb. All the subjects were given detailed information on the type of test they were going to do and the objectives, with particular emphasis on the need to apply the greatest possible degree of muscular strength in both hands in the case of the strength evaluation and to maintain a given strength value during the fatigue assessment.

Following the statistical studies performed from these records, the variables of gender, age and dominance were selected as being necessary to segment the database. Moreover, they also made it possible to select the following variables, basic to evaluate the hand’s functional ability (Figure 2):

- Percentage of normality of the strength measurement.
- Coefficient of variation of the repetitions performed.
- Percentage of normality of the Coefficient of Variation.
- Index of Loss of Strength of the affected side with regard to the healthy side.
- Index of Loss of Strength of the affected side with regard to Normality.
- Index of fatigue for 25%, 50% and 75% of maximum grip strength.

Finally, during Phase 3, work focused on facilitating the use of this new application by the user. For this purpose, the type of information that might be of interest for a functional assessment of the hand was defined, such as the graphic information of measurements and the database or tables of results and assessments. Moreover, a software was developed capable of: 1) guiding the user throughout the process of measuring the subjects and 2) automatically generating the results reports, containing the most relevant information for proper assessment by the professional (Figure 3).
**Characteristics of the NedMano/IBV application**

Following the research and complex development process, the NedMano/IBV application was generated. It has the following characteristics:

- **Parts:**
  - NedVEP/IBV hand isometric dynamometer to record strength.
  - Software that makes it possible to manage patient data, as well as to take multi-session recording for exhaustive monitoring of patient evolution.
  - Database of the Spanish population segmented according to age, gender and dominance to enable the results of each subject to be compared to the normality reference values.

- **Measurement protocol:**
  - The average use time of the NedMano/IBV from the preparation of the subject to the generation of the automatic report is estimated as 20 minutes.

- **Biomechanical variables recorded directly:**
  - Maximum strength in the gestures of Grip, Lateral Pinch and Distal Pinch.
  - Reduction in isometric strength over time when the subject tries to maintain 100%, 75%, 50% and 25% of their maximum strength.

- **Parameters assessed:**
  - It rates the dominant and opposite hand and the relationship between both. These assessments are based on the comparison between the affected and the healthy hand (if there is one), and with the normality database.
  - It assesses parameters pertaining to maximum hand strength: Maximum Voluntary Contraction, Mean Strength, Coefficient of Variation and Indices of Loss of Strength (opposite side and with regard to normality).
  - It assesses the fatigue produced during the grip gesture: Fatigue index, at 100% of the Maximum Voluntary Contraction (MVC), at 75% MVC, at 50% MVC and 25% MVC.

- **Other utilities:**
  - Graphic representation of strength curves versus normality bands.
  - Fully automatic generation of Word-format reports, including patient data and the results of the tests carried out.
  - Integration of the results in the Assessment Database, allowing the user to have centralised information pertaining to assessments performed on a given patient with any Ned/IBV assessment application.

**Conclusions**

The new NedMano/IBV application permits an objective and repeatable assessment of the subject’s functional ability for grip, distal and lateral pinch, fundamentally for multiple daily-life activities. This assessment is based on maximum strength and fatigue records that are compared to a database of healthy subjects. This provides professionals in the sector with a new protocol that can be performed in 20 minutes and which offers useful and easy-to-interpret information in their assessment of the hand.

**Acknowledgements**

We are grateful for the opinions of the users of the Ned measurement equipment, that always guide us in improving our work to deliver a more objective functional assessment of patients. Moreover, we also wish to express our recognition to everyone that participated in the experimental sessions to create this database.

CUSTOMER SERVICE: **902 176 419**

atencion.cliente@ibv.upv.es
Ergonomic seats for rope access works

Nicolás Palomares Olivares1, Guillem Josep Cortes i Carbonell1, José Navarro García1, Alberto Ferreras Remesal1, Alfonso Oltra Pastor1, Raquel Ruiz Folgado1, Carlos García Molina1, Rosa Porcar Seder1

1 Instituto de Biomecánica de Valencia
2 Grupo de Tecnología Sanitaria del IBV, CIBER de Bioingeniería, Biomateriales y Nanomedicina (CIBER-BBN)

INTRODUCTION

Rope access work refers to temporary operations at heights performed through techniques of access and positioning with ropes. The purpose of this type of techniques is to perform work in areas that are difficult to access (facades, wells, electricity towers, etc.), where the installation of other traditional systems, such as scaffolding, is complex or involves a high risk.

The main risks to which workers operating at heights are exposed are:

- **Risk of falling from a height**: The worker is injured as a result of the impact of falling from a certain height.
- **Risk of musculoskeletal disorders**: Awkward postures increase the risk of musculoskeletal lesions, particularly in the lower back area. In addition, repetitive movements can affect the shoulder, elbow and wrist joints.
- **Risk of trauma through suspension**: The restriction of the movement of the lower extremities and the pressure caused by the harness can lead to alterations in the vascular system, increasing the probability of causing serious risks to their health.
- **Other possible risks**: Impact with stationary objects, knocks or cuts by objects or tools, falling objects, etc.

Of the risks described above, the most frequent ones are those associated with musculoskeletal disorders. One of the key aspects for the reduction of this risk is the use of a seat designed specifically for rope access work, avoiding ergonomic problems, and also helping to improve worker safety.

Although the use of an ergonomic seat is of vital importance, at the moment seats used in rope access work are not governed by legislation in terms of the requirements of ergonomic design to be met.

As the use of a seat is a regulatory obligation and requirements are not defined, there is a need for the implementation of a specific study on rope access work.

The study was carried out by researchers of the Instituto de Biomecánica (IBV), on request by Comissions Obreres del País Valencià (CC.OO-CV) and with the funding of Fundación para la Prevención de Riesgos Laborales (FPRL), performed a study whose objective was to improve the Culture of Prevention in rope access work.
A detailed study was performed, examining the risks associated with rope access work, the different typologies of seats that are currently on the market and the most important characteristics to be addressed in the seat. The study involved a discussion group with workers from the sector, as well as field tests by means of a simulation with workers specialised in the actual conditions of rope access work.

**RESULTS OBTAINED**

The study made it possible to improve the culture of ergonomic prevention in the sector involved in rope access work to minimise the risks to which such workers are exposed, as well as the adoption of good practices in the use of the seat. The results are completed with the establishment of minimum ergonomic criteria that conventional (commercial) seats should meet and with the proposal for the conceptual design of a new seat based solely on ergonomic criteria.

--- **Ergonomic criteria in the design of a seat for rope access work** (Figure 2): Using one of the seats best rated by the workers (a seat with integrated harness), seat specifications were generated to improve the ergonomic conditions of the work station.

--- **New seat concept for rope access work** (Figure 3): From the essentially ergonomic standpoint, a new seat concept, adapting workstation to worker needs, is proposed. This change in seat concept seeks to reduce the ergonomic risks associated with rope access work.
associated with this activity, particularly the reduction of musculoskeletal disorders.

The generation of the new seat concept was intended to keep the worker's body closer to the facade or structure and guarantee leg support in a rigid base used to transfer weight to the lower extremities.

**Finished products**

The products generated by the study are a manual and an information leaflet for people rope access work. These documents are intended to provide workers in the sector with the necessary information for the identification and improvement of the ergonomic risks involved in their work. The contents focus on identifying possible risks of injury derived from this type of work, prevention and protection measures for the worker and finally recommendations pertaining to the seat concept.

The manual and the information leaflet are both available as a digital download from the IBV web site [http://laboral.ibv.org/](http://laboral.ibv.org/) in the Occupational health area.

**Conclusions**

It is evident that the seat for rope access work is an indispensable part of the equipment needed to reduce work-associated risks. The use of an ergonomically suitable seat should guarantee user comfort and reduce ergonomic risks.

Moreover, guidelines have been generated to improve ergonomic prevention culture in work at heights, as well as good seat use practices. Similarly, minimum ergonomic criteria have been established for current seats and a new ergonomics-oriented seat concept has been conceived.

Finally, it should be remembered that end users, rope access workers, were involved in study, and their opinion and experience helped to shape the different recommendations obtained.

**Acknowledgements**

We would like to thank Vértice Vertical, Alaire and Cobra, companies that engage in work at heights, for their collaboration in the project. The work was funded by the Fundación para la Prevención de Riesgos Laborales through its Announcement of Assignment of Resources 2010.
Cuidamos tu calidad de vida

ibv.org