A research to design clothes based on anthropometrics and usability needs of wheelchair users

Development of new technologies for the flexible and eco-efficient production of customized healthy clothing, footwear and orthotics for consumers with highly individualised needs

European congress on Innovations in Textiles for Health Care
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Introduction to the FASHION-ABLE project

• FASHION-ABLE is a three-year European project belonging to the 7th Framework programme.

• FASHION-ABLE project will enable the conception, co-design and the sustainable manufacture of fully personalised products for three highly challenging target populations:
  • Fashionable clothing for physically disabled people requiring a wheelchair
  • Fashionable footwear for diabetics developing diabetic feet
  • High-performing textile compression bandages for sufferers from acute periods of musculoskeletal disorders

• Product-related knowledge and technologies developed include:
  • Involving users and orthotic technicians in the definition of product requirements
  • Introducing new finishing operations to locate multiple on-demand physiological properties in specific areas of the product
Introduction to the FASHION-ABLE project

14 PARTNERS
6 COUNTRIES

<table>
<thead>
<tr>
<th>Short name</th>
<th>Country</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBV</td>
<td>Spain</td>
<td>RTO</td>
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<tr>
<td>IConverter</td>
<td>Italy</td>
<td>SME industrial</td>
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<td>Calzamedi</td>
<td>Spain</td>
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<td>Bivolino</td>
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<td>BSN</td>
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<td>KnopfSohn</td>
<td>Germany</td>
<td>SME industrial</td>
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<td>Synesis</td>
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<td>SME service-to-industry</td>
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<td>ATC</td>
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<td>HS</td>
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<td>SME service-to-industry</td>
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<td>EURATEX</td>
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<td>SME Association</td>
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<td>Poland</td>
<td>End-user Association</td>
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NOW, **mass customization** offers an **added-value** to “**majority public**” already covered by the **ready-to-wear** offer...

...**WHILE** ready-to-wear clothes are designed neither to fit **wider variety of body shapes** nor **sitting postures**

“For this challenging target population **personalization IS NOT JUST AN ADDED-VALUE BUT A REAL NEED** affecting their **QUALITY OF LIFE”**
Background

HEALTH & SAFETY PROBLEMS

- Risk of slips, trips & falls
- Put in/out difficulties
- Restricted movements
- Impossible fitting
- Risk of entanglement
- Higher vulnerability to fire
- Lower durability due to different wear areas
- Increased sweat areas
- Lower energy consumption
- Hygiene difficulties
- Frequent stains (saliva, mucus, urine, etc.)
- Spastic reactions
- Higher vulnerability to weather conditions
- Venous diseases
- Skin fragility and ulcers
- Skin incompatibilities
- UV intolerance

REQUIREMENTS

- Mechanical reinforcement
- Ease of use
- Adequacy to joint mobility
- Posture matching
- Anthropometry matching
- Anti-entanglement
- Flame retardant/resistant
- Wear/tear resistance
- Moisture management
- Perspiration control
- Thermal insulation
- Anti microbial/bacterial
- Repellence/stain-resistance
- Pressure control
- Tissue regeneration
- Friction control
- Anti-allergic/biocompatible
- UV protection

PRODUCT ADAPTATIONS

(according to user physical, physiological and functional attributes)

- Additional special elements
- Individual patterns
- Special mechanical properties of materials
- Special featured yarns
- Special functional treatment
- Special tribological properties of textiles
Phase 1. User needs and requirements

**Bibliographic review**

To study the main physiological and biomechanical characteristics of disabled people requiring a wheelchair.

**Focus groups with wheelchair users**

- Visit PREDIF: 17 users
- Users with different level of autonomy

**USER NEEDS**

- Usability and safety
- Movement restriction
- Fitting and pressure
- Comfort
- Thermal comfort
- Sensitivity and textiles preference
- Preference of closing systems

**Focus groups with caregivers**

- Visit PREDIF: 5 caregivers
- Discuss the aspects mostly related with functionality and skin damage

**Inquiries to wheelchair users**

64 users:
- Comfort
- Fit
- Skin sensitivity
- Thermal comfort
- Protection
- Aesthetics
- Preference of textiles
### Phase 1. User needs and requirements

<table>
<thead>
<tr>
<th>FUNCTIONAL ASPECTS</th>
<th>OBJECTIVE/GOAL</th>
<th>DESIGN PROCESS INVOLVED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fitting</strong></td>
<td>Need of loose fitting in the neck, chest, abdomen, bottom and legs. Need of longer leg lengths and longer back of shirts, sweaters, jackets and coats.</td>
<td>• Pattern configuration&lt;br&gt;• Textile mechanical properties</td>
</tr>
<tr>
<td><strong>Usability</strong></td>
<td>Need of specific openings to facilitate the put on / take off process.</td>
<td>• Pattern configuration</td>
</tr>
<tr>
<td><strong>Freedom of movement</strong></td>
<td>Paraplegics prefer zips, Velcro and elastic bands. Quadriplegics prefer Velcro or elastic bands.</td>
<td>• Cloth complements</td>
</tr>
<tr>
<td><strong>Perspiration</strong></td>
<td>The presence of moisture in the garment or between the garment and the chair may contribute to the appearance of infections. Moisture may increase friction and produce blisters and ulcerations. Users sweat the most at the bottom, chest, dorsal, lumbar, neck and abdomen areas.</td>
<td>• Textile thermal properties&lt;br&gt;• Pattern configuration</td>
</tr>
<tr>
<td><strong>Thermal isolation</strong></td>
<td>The lack of thermal feeling of paraplegics and quadriplegics has to be considered when designing the garment. The garment must protect the body against hot and cold environments. Main areas suffering thermal discomfort are lower limbs and hands.</td>
<td>• Textile thermal properties&lt;br&gt;• Pattern configuration</td>
</tr>
<tr>
<td><strong>Friction</strong></td>
<td>Friction between clothes and the chair must be avoided to prevent the appearance of injuries. It is important to increase durability of garments in the areas with more friction.</td>
<td>• Textile mechanical properties&lt;br&gt;• Pattern configuration</td>
</tr>
<tr>
<td><strong>Aesthetics</strong></td>
<td>A comfortable and suitable garment is not opposite to a fashionable and trendy garment. Users claim for more aesthetical garments.</td>
<td>• Textile aesthetical properties&lt;br&gt;• Pattern configuration</td>
</tr>
</tbody>
</table>
Phase 1. User needs and requirements

ANTHROPOMETRIC CHARACTERIZATION

1. Use anthropometric databases for wheelchair users:
   - These are focused in anthropometry related to the environment (i.e. accessibility, etc.)
   - These data are not enough for the project’s purposes

2. Generate an anthropometric database
   - Taking advantage of IBV’s databases of 3D scanned people in standing and seated posture
   - This database contains the necessary measurements according to experts for cloth personalization
Hypothesis: the main anthropometric difference between wheelchair users and healthy people comes from the different postures they have, seated vs standing

- Extract the differences between seated and standing anthropometries
- Establish their relation
Phase 1. User needs and requirements

Extract a manageable database of approx. 120 people (above 16) representing the complete population diversity

3. Customize the measurements for users who can keep an upright position
   - Newly developed protocol in which measurements are directly taken from the user
   - Use of a wheelchair without back
Phase 1. User needs and requirements

CHARACTERIZATION OF MATERIALS

A mannequin reproducing human bottom, including the skeletal structure and the soft tissue

A pressure sensor mat to measure the pressure patterns for the different materials.
Phase 2. Prototypes and user tests

Prototype clothing with new functionalities based on the knowledge preliminarily generated and also based on the anthropometric measurements.
User tests were carried out with 20 users: quadriplegics, paraplegics and users with cerebral palsy

Testing protocol

• Anthropometric characterization
• Dressing up
• Usability questionnaire
  ✓ Facility of putting on and taking off
  ✓ Preference about the garments’ textiles and closing systems
  ✓ Possibility of incorporating a hydrophilic, hydrophobic, slippery, repelling bad smell, repelling dirt, anti-bacteria, and anti-static spray-finishing functionality on determined areas
• Fitting questionnaire
  ✓ Fitting perception (user and expert) and preference (user) per body area
Anthropometric design criteria: A set of linear regression equations were defined to enable to manufacture a completely custom-made garment to ensure a proper fitting.

\[ D.V_i = C_0 + C_1 \times \frac{\text{Body.measurement}}{\text{Clothing.dimension}} + C_2 \times I.V_2 + \ldots + C_n \times I.V_n \]

**Dependent variable:**
The one that shows a higher correlation with the body/clothing ratio, either:
- Users fitting perception
- Expert fitting perception
- Users fitting preference

**Key parameter**

**Independent variables:**
- Ratios between body measurements and clothing dimensions
- Age
- Height
- Weight
- BMI

To solve the clothing dimensions give a certain value to the fitting dependent variable
Usability design criteria: A set of recommendations was generated depending on the garment and the users’ disability.

- **Overtures** (for improving the fitting)
- **Closing-opening systems** (for making easier to dress/undress)
- **Textile properties** (such us elasticity, breathability, etc.)
- **Optional elements** (pockets, aesthetical elements, etc.)
Phase 4. Online configurator

• Overtures

• Closure-opening systems

• Textiles

Users can select the closure-opening systems on the chest and on the cuffs. Also if they want a roll-up sleeves system.

Users should choose the number, shape, position and material of these elements.

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Users should choose the number and position of these elements.

Users should choose the number and position of these elements.

Users should choose the number and position of these elements.

Buttons, an Elastic band, Snaps and Velcro are the most suitable closure elements.

An Elastic band, Snaps, Velcro, and Magnetic buttons are the most suitable closure elements.

Elastic bands are not suitable for caregivers who grab users from the cuffs to dress them, since they need to be resistant.

Chose chest or cuff for the closure-opening system:

- Chest
- Cuffs
- Roll up sleeves

No closing systems
Phase 4. Online configurator

• Overtures

• Closure-opening systems

• Textiles

Users can select the closure-opening systems on the chest and on the cuffs. Also if they want a roll-up sleeves system.

Users should choose the number, shape, position and material of these elements.

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Users should choose the number and position of these elements.

**Buttons, Velcro and Snaps** are the most suitable closure elements.

**Snaps** and **Velcro** are the most suitable closure elements.
Phase 4. Online configurator

Your wheelchair shirt configurator.

Tell us your Age, Collar size, Weight, Height and fill in your full细化 measurements.

Please let us your Age, Collar size, Weight, Height.

[Screen shot of a webpage showing the configurator]

Your wheelchair shirt configurator.

Choose your front: Paraplegics prefer buttons or zip in the chest, Tetraplegics prefer snaps Velcro or zips.
Phase 4. Online configurator

Your wheelchair shirt configurator.

Choose your type of sleeve: Flex sleeve, Velcro cuff, 2 button cuff, Short sleeves.

Para-pleat prefers buttons, snaps, Velcro or elastic bands in cuffs.

Tetraplegia prefers snaps, Velcro or elastic bands.

Long-sleeve button-down

- Normal 2 button cuff
- Short sleeves

Your wheelchair shirt configurator.


How “Outlast” technology works:
1. Outlast microcapsules absorb excess heat.
2. Stored heat is released to the body as needed.
3. The result is a balanced microclimate.

Features of Outlast fabrics with PCM fibres:
- Less overheating
- Less chill
- Less perspiration
- Adapts to your thermal needs
- Active temperature regulation
- Oeko-Tex Standard 100
- Outlast fabrics create well-being.
Phase 4. Online configurator

FASHION-ABLE in the European Paralympics Wheelchair Rugby

Bivolino experienced tailor-made shirts for the Belgium EU tetraplegic rugby team:
(www.ecwcrugby2013.be European championship Wheelchair Rugby 2013)

Made-to-measure ordered online with focus on functional materials and style options.
Future work

Future work in this project is aimed at:

1. Incorporating 3D spacer materials to desired areas of the garments
   - ![3D spacer materials](image1)
2. Incorporating stretch leathers
   - ![Stretch leathers](image2)
3. Localised functionalization of fabrics by means of spray finishing
   - ![Spray finishing](image3)

**Materials:**
- Fluorocarbon (oleophobic)
- Polyester-copolymer (hydrophilic)
- Grey: original fabric (slightly hydrophobic)
THANK YOU FOR YOUR ATTENTION!

http://www.fashionable-project.eu/
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