

UNIVERSITY OF WEST HUNGARY
Simonyi Karoly Faculty of Engineering, Wood Sciences and
Applied Arts

WEAR COMFORT IMPROVEMENT OF MEDICAL AIDS USED
FOR SPINE DEFORMITY TREATMENT

PhD dissertation
Book of theses

ORSOLYA NAGY SZABÓ

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PhD school: Jozsef Cziraki Doctoral School of Wood Sciences and Technologies
Leader: Prof. Dr. László Tolvaj university professor

Program: Fiber technical sciences
Leader: Dr. András Winkler professor emeritus

Field of science: Material sciences and technologies

Supervisors: Dr. habil. István Patkó university associate professor
Dr. habil. Márta Kisfaludy university associate professor
Dr. Zoltán Koczor †

1. Preliminaries of research

One of the frequently applied rigid plastic treatment of scoliosis is the Chéneau brace. However, wearing this brace causes serious mental, physical and physiological difficulties for youngsters between the age of 8 and 18 years, since this medical aid has to be worn 23 hours a day for years. The author joined project Gerinco2 TECH-08-A 1/2-2008-0121 titled „Development of intelligent equipment and method for the observation and treatment of orthopedic deformities” as an external college, i.e. apparel industrial expert. Among others, the Budapest University of Technology and Economics, the Semmelweis Medical University and SalusKft. took part in this project.

2. Determination of research aims

The aim of research is to improve the physiological comfort of brace wearers regarding the presently used brace material. Chéneau brace is a 5 mm thick plastic “armor” that weighs between 0.9 and 1.5 kg depending on the size. This brace fits on the waist, follows the contours of the upper body loosely and presses a few medically determined points as a healing treatment. In order to improve physiological comfort the Author determined the following aims regarding the perforation of the brace, the optimal selection of the fabric worn under the brace and the adequate formation of the underwear:

- The aim of research is to find functional and intelligent fabrics and to examine their properties that affect thermophysiological comfort. Based on the survey of the brace wearers’ opinion commercially available conventional T-shirts as well as T-shirts developed for sports are not suitable for wearing under the brace.
- A further aim of research is to develop a dimensioning method with the help of which T-shirts made of different strain materials compress the body with the same force, prevent the T-shirts from wrinkling and slipping up under the brace. Using this method the correction value the pattern size should be modified with can be determined for fabrics with different strain values.

- Based on the survey of the brace wearers' opinion the prototype of the T-shirt that can be worn under the brace in a way that the cutlines do not touch the pressure points was created. Based on the subjective testing by the brace and the T-shirt prototype wearers the Author improved the possibilities to place the cutlines and prepared further T-shirts and underwear products with different cutline positions according to the demands, as well as created a special brace cover.
- Based on the strength tests of the brace material with different diameter bores in order to improve the ventilation of the brace the Author determined the extent of strength decrease as a function of the ratio of the perforated surface, the number, diameter and location of bores regarding a determined area.
- The Author examined whether the ventilation bores in a brace have positive impact on the wearer's microclimate based on the objective and subjective measurements of the body – T-shirt – brace – external environment interaction in a climate chamber at different temperatures.

3. Examination method, examined samples

The development of garments worn under the brace requires research in several scientific fields. In the interaction system between the body and the fabric the properties of the fabric that influence the physiological feeling have to be examined. This was carried out with the subjective testing of the T-shirts made from these fabrics and the examination of the fabrics by the Author.

In order to plan the underwear the demands of the aimed people have to be determined beforehand using surveys, then the adequate constructional method has to be determined for shape formation and sewing technology has to be found also for execution. The ventilation of the brace can be improved with perforation the creation of which is based on the results of 3 point bending tests of the brace material. The examination of the physiological impact of the body – fabric – brace – external environment system was carried out in a climate chamber at preset parameters so that the results can be evaluated both subjectively and objectively.

3.1. Information gathering based on surveys and interviews

The Author mapped the brace wearers' problems with surveys and interviews, executed several in-depth interviews with the orthopedic technician at Salus Kft. as well as with physiotherapists who helped children wearing braces in their healing. Information gathered during discussion with the children and their parents helped the adequate forming of the underwear below the brace.

3.2. Measurement methods of material examination

Based on the objective and subjective testing of functional fabrics in a previous project, the Author chose some functional Coolmax fabrics with special properties and Outlast brand fabrics that contain different capsules that change phase (PCM) besides the conventional cotton and polyester based underwear fabrics so that the Author can optimally choose the fabric of the underwear worn below the brace. Among the fabrics there some that help health protection and life quality improvement due to their composition or structure. The data of the examined samples are listed in Table 1.

The dissertation involves the results of examining the following fabric properties:

- water absorption capacity,
- water wicking ability,
- air permeability,
- abrasion resistance,
- strength and flexibility properties.

Fabric name	Commercial name	Material composition	Area density [g/m²]	Thickness [mm]	Fabric structure
Cotton	Cotton	97% cotton, 3% elastane	242	0.64	single weft knitted
PES	Polyester	97% PES 3% elastane	206	0.52	single weft knitted
Coolmax	Coolmax Fresh FX 70400	100% PES Coolmax	168	0.73	overnit Swiss piqué knitted
OU White	Outlast White OE55782	66% cotton, 28% viscose 6% elastane with PCM capsules	198	0.64	single weft knitted
OU Fraser	Outlast Fraser OE09PJ COS89	95% cotton, 5% elastane with PCM capsules	146	0.55	single weft knitted, surface treated
OU Black	Outlast Black OE55783	66% lyocell, 28% viscose, 6% elastanewith PCM capsules	175	0.56	single weft knitted
OU Shirt	Outlast Climastar	59% PES 39% viscose, 2% elastane with PCM capsules	192	0.68	rib knitted

Table 1: Examined samples

3.3. Construction and modelling of underwear based on fabric tensile tests

In order to improve the construction method of underwear products the Author worked out a dimensioning process based on the strain values of tensile tests with the help of which the course and wale direction strain values of a fabric (named Cotton) with adequate strain belonging to a certain force can be read from a tensile test diagram and the strain value belonging to the same force of other fabrics can be determined. Based on these values the course and wale direction value of construction under the brace can be determined.

3.4 Strength analysis of the brace material

HDPE (high density polyethylene) plastic – material of the brace – is advantageous considering medical aspects however has disadvantages from garment physiological point of view, especially regarding air permeability and moisture wicking ability. In case of higher external temperature or intensive movement it creates an especially uncomfortable microclimate for the brace wearer. In order to increase air permeability of the brace, the Author determined 5-10-20-30% ratio of different size holes in the brace material referred to the area of the examined sample. The most advantageous bore pattern can be chosen if the influence of the size, number and position of holes on the strength properties are considered. The dimensioning process based on the three point bending test of perforated sheets creates a relationship between the stress that evolves in the material and the size and number of holes in the brace material.

3.5 Design and arrangement of cutlines of T-shirts worn under the brace

The technological design of T-shirts worn under the brace influences the comfort of wearing to a great extent. Besides the properties of the base material the “pressure points” of the brace have to be considered when placing the cutlines. If the material wrinkles or there is a sewing line under the pressure points of the brace serious skin damage may occur. Since this posture correction equipment is prepared based on individual measurement, the three pressure points are differently placed in case of everyone but can usually be found on the back and lateral part of the trunk. Based on her observations and the study of the relevant literature the Author designed 3 different T-shirt variants that fulfill the requirements of brace wearers. It is also possible that a unique pressure point variant occurs, in that case the cutlines can be moved based on the thermovisional image, therefore all needs can be met.

3.6 Garment physiological measurements

Garment physiological measurements were carried out in the Laboratory for Clothing Engineering, Department of Textile Materials and Design Maribor University, where the Author was the test person in the experiments carried out in a climate chamber. In the complex examination series she wore T-shirts made from the 3 materials listed in Table 1,

i.e. Cotton, Coolmax and OU White for a given time in the climate chamber at temperatures of 25°C, 28°C and 32°C at constant air movement, and carried out passive and active activities according to the program in unperforated and perforated braces. The aim of the examination was to prove that the wearer's comfort is improved if the brace has 5% ventilation holes.

4. Theses of research

Thesis 1

The Author worked out a dimensioning process for the construction of underwear patterns based on tensile tests. If this process is applied the same compression force is exerted on the body when wearing underwear made from different elasticity and large strain fabrics and this way provides adequate comfort. The essence of the dimensioning process is that the course and wale direction strain belonging to the tensile force considered to be adequate according to wearing trials can be determined from the course and wale direction tensile test curves of the given material. This way the value of construction under the brace can be calculated. This way the fabrics with different flexibility do not wrinkle on the body and do not cause skin damage under the brace.

Thesis 2

The Author created the optimal positioning method of cutlines on T-shirts that can be worn under the brace taking into consideration that cutlines have to avoid pressure points of the brace. Using this method the Author worked out three cutline combinations. T-shirts produced using these cutline combinations suit most brace wearers therefore can be used in series production economically. For whom these T-shirts are not suitable the position of cutlines can be modified individually based on thermovisional images and hence a unique T-shirt can be produced with small extra cost.

Thesis 3

The Author worked out a mechanical dimensioning process based on three point bending tests for the determination of position, size and number of holes that increase the air permeability of the brace. The diameter of holes for areas of any size as well as the number of holes if the ratio of perforated area is known can be determined using this process.

This process makes it possible to determine the ratio of perforated area, the force, the limit bending stress can be determined for the examined specimen size in case of a given brace material as a function of the number and diameter of holes from the diagram created using this process.

Thesis 4

The Author proved with measurements carried out in a climate chamber that the perforation of the brace surface has positive impact on the physiological state of the test person. Based on the results of measurements carried out at temperatures of 25°C, 28°C and 32°C set in a climate chamber, at constant air movement and humidity while carrying out different activities in a brace without and with 5% perforation, in T-shirts made from three different base material the Author found that:

- 4.1 During the measurements in case of perforated brace the weight loss of the test person at 25°C climate chamber temperature was 10-20% less, at 28°C climate chamber temperature 8-16% less, while at 32°C climate chamber temperature 11-22% less than in case of the unperforated brace.
- 4.2 During the measurements in case of perforated brace the moisture absorbed by the T-shirt worn under the brace at 25°C climate chamber temperature was 31-35% less, at 28°C climate chamber temperature 44-46% less, while at 32°C climate chamber temperature 13-28% less than in case of the unperforated brace.
- 4.3 During the examinations in case of perforated brace the average value of temperature measured on the skin surface at 25°C climate chamber temperature was 0.3-0.4°C less, at 28°C climate chamber temperature 0.5°C less, while at 32°C climate chamber temperature 0.3-0.4°C less than in case of the unperforated brace.
- 4.4 During the examinations in case of perforated brace the average value of humidity measured on the skin surface at 25°C climate chamber temperature was 1.1-3.8% less, at 28°C climate chamber temperature 1.1-3.8% less, while at 32°C climate chamber temperature 1.6-5.4% less than in case of the unperforated brace

Thesis 5

The Author proved using weighed ranking based on objective fabric tests and the comparison of subjective evaluation of brace wearers' that out of the 5 fabrics used in both tests the OU Black fabric is the most suitable for wearing under the brace regarding brace wearing aspects.

5. Own publications related to research

Journal paper (peer-reviewed – in English)

Nagyné Szabó Orsolya – Koleszár András: Garments under brace life quality improve affect experiment of technology and physiology *Biomechanika Hungarika VI. évf. 2013/1. szám pp.67-74. (ISSN:2060-4475)*

Journal paper (peer-reviewed – in Hungarian)

Nagyné Szabó Orsolya - KoleszárAndrás - Dr. TamásPéter: Ruhaszerkesztés egyéni méretre 3D-s tervezőrendszerben *Magyar Textiltechnika LX. évf. 2007/3. szám p.66 - 68.(ISSN 1788-1722)*

Conference publications (international conference – English proceedings, published, peer-reviewed)

Orsolya Nagy Szabó, András Koleszár: Improve garments quality under brace
International Joint Conference on Environmental and Light Industry Technologies
(Óbuda University) Budapest, Hungary 2013, november 20-22. (ISBN: 978-615-5018-93-0)– accepted

Orsolya Nagy Szabó, Tibor Gregász: Thermal camera study of medical brace wearing
International Joint Conference on Environmental and Light Industry Technologies
(Óbuda University) Budapest, Hungary 2013, november 20-22. (ISBN: 978-615-5018-93-0) – accepted

Gersak J., Halász M., **Nagy Szabó O.**, Koleszár A.: 3D body datas Integration in functional wear under brace. 12th AUTEK World Textile Conference, 13th to 15th June 2012, Zadar, Croatia, Book of proceedings, pp 1023-1028, ISBN 978-953-7105-44-0/-48-8/-49-5

Orsolya Nagy Szabó, András Koleszár: Comfort feeling in brace. 3rd International Joint Conference on Environmental and Light Industry Technologies, Budapest, Hungary 2012.november 21-22. Budapest (ISBN: 978-615-5018-34-3)

Orsolya Nagy Szabó, András Koleszár: Clothing physiology test in climat chamber. XXVI. microCADInternational Scientific Conference (Miskolc University), Miskolc, Hungary 2012

Orsolya Nagy Szabó, Koleszár A., Gersak J., Halász M.: Functional T-shirt Under Brace. 2nd International Joint Conference on Environmental and Light Industry Technologies. 2011. November 21-22. Budapest, Hungary pp. 63-70, (ISBN: 978-615-5018-23-7)

Orsolya Nagy Szabó, András Koleszár: Functional Design and Testing of Corset under Linen. XXV. microCAD International Scientific Conference (Miskolc University), Miskolc, Hungary 2011. pp. 49-54 (ISBN: 978-963-661-971-8)

Orsolya Nagy Szabó: Corset and clothing physiology. 1st International Joint Conference on Environmental and Light Industry Technologies, 18 – 19 November 2010, Budapest, Hungary, Óbuda University pp. 323-328 (ISBN: 978-615-5018-08-4)

Orsolya Nagy Szabó, András Koleszár: Patterns for corset wearing children. 1st International Joint Conference on Environmental and Light Industry Technologies, 18 – 19 November 2010, Budapest, Hungary, Óbuda University pp.441-445 (ISBN: 978-615-5018-08-4)

Conference publications (Hungarian conference –Hungarian proceedings)

Nagyné Szabó Orsolya: Alsóruházat technológiai és fiziológiai kísérletei. Textil-ruha-bőr Jubileumi Konferenciaés Alumni fórum (Óbuda University) Budapest, 2012, Június pp. 14-18. (ISBN: 978-615-5018-34-3)

Nagyné Szabó Orsolya, Koleszár András: Special underwear for young girls having scoliosis problem. XXIV. microCAD International Scientific Conference (Miskolc University), Miskolc, Hungary 2010. pp. 37-43 (ISBN: 978-963-661-925-1)

Nagyné Szabó Orsolya: Egyedi méretű alsóruházat kialakítása korzettet viselők számára 2D-s rost és egyéb szerkezetű alapanyagok felhasználásával. Doktorandusz Konferencia (Nyugat-Magyarországi Egyetem) Sopron, Magyarország 2010, június 4. Abstracts: pp.24

Nagyné Szabó Orsolya- Koleszár András: Speciális alsóruházat kialakítása korzettet viselők számára .Trends and technologies in environmental protection and light industry International Scientific Conference (Budapest Tech Polytechnical Institution) Budapest, Hungary 2009, november 12. pp. 53-59 (ISBN: 978-963-7154-98-0)

Conference lecture (in English)

Orsolya Nagy Szabó, András Koleszár: Improve garments quality underbrace. International Joint Conference on Environmental and Light Industry Technologies (Óbuda University) Budapest, Hungary 2013, november 20-22.

Orsolya Nagy Szabó, Tibor Gregász: Thermal camera study of medical brace International Joint Conference on Environmental and Light Industry Technologies (Óbuda University) Budapest, Hungary 2013, november 20-22.

Orsolya Nagy Szabó, András Koleszár: Comfort feeling in brace. 3rd International Joint Conference on Environmental and Light Industry Technologies, Budapest, Hungary 2012.november 21-22. Budapest,

Orsolya Nagy Szabó, Koleszár A., Gersak J., Halász M.: Functional T-shirt Under Brace, In: 2nd International Joint Conference on Environmental and Light Industry Technologies. 2011. November 21-22. Budapest, Hungary

Orsolya Nagy Szabó, András Koleszár: Functional Design and Testing of Corset under Linen. XXV. microCAD International Scientific Conference (Miskolc University), Miskolc, Hungary 2011.

Patent

Orsolya Nagyné Szabó 45%, András Koleszár 45%, Marianna Halász, PhD 10% requested a patent under number P1300383 at the Hungarian Intellectual Property Office in June, 2013 under title: Underwear product that can be worn under an assistive brace.

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Connected to the patent request the copyright request – figure sensus -. No. M1300398 was registered as a copyright under number 211912 by the Hungarian Intellectual Property Office.