Project title	**Adapted Performance wear (SHAPE)**
Project duration	December 2017- December 2018; 24 months
Type project/ funding	IWT TETRA HBC.2016.0078
Project partners	University College Ghent, HOGENT (coordinator) Gent University
Total project costs	€ 435147.25
Total MM	48
Total funding	€ 402.512

Project Coordinator

Organization	University College Ghent (HOGENT)
Project leader	Alexandra De Raeve
Function	Head of department Fashion, Textiles and Wood Technology (FTILab)
Faculty/ Department	Faculty of Science and Technology
Address	Buchtenstraat 11, 9051 Sint-Denijs-Westrem
Phone	0478 97 01 67
Email	alexandra.deraeve@hogent.be

Project co-applicant

Organization	Ghent University (UGent)
Project leader	Prof.dr.ir. Lieva Van Langenhove
Function	Full Professor
Faculty/ Department	Faculty of Engineering and Architecture Department of Textiles
Address	Technologiepark 907 – 9052 Zwijnaarde
Phone	09 264 54 19
Email	lieva.vanlangenhove@ugent.be

End User Committee

Met de steun van

Contents

Foreword

Sportswear is based on sizing tables developed on a basis of average body sizes and will therefore not fit population groups with body proportions categorically different from average (e.g. athletes from different sport disciplines, disabled people or people with specific professions). This is not only detrimental for the aesthetics and comfort of the wearer but also in stark contrast with functionality (e.g. orthopedic products; sportswear meant to offer some support, to improve performance or to facilitate fast revalidation; some intelligent textiles for monitoring) and the changing demands of the consumers who lose their tolerance for regular products and have become more and more demanding for garments with a personalized fit. These groups of products require an optimal contact with the skin, they have to fit, otherwise they lose their functionality.

The overall objective of SHAPE project Adapted Performance Sportswear was to develop comfortable, fitted and functional (sports)wear for population groups with body shapes and proportions different from the average population. The aim of the project was to gain better insight in anthropometric differences (average population versus various groups of athletes) and work out a methodology for translating this information effectively into garment production. In addition, the concept of wear comfort and compression was further explored in relation to the materials and fit.

During the execution of SHAPE project the anthropometrics of elite cyclists and rowers were assessed. Two types of scanning techniques/principles were employed: 1) structured light 3D Body scanning by a state-of- the-art 3D body scanner and 2) photometry/photographing (i.e. measurements extracted from 2D pictures). Moreover, variation of body measurements and pressure upon (sport-specific) postures were investigated. As a result size charts were developed. Secondly a large collection of fabric for sportswear was tested for their comfort and functional properties. Finally several prototypes of sports gear for elite rowers and G-sport cyclists were designed and evaluated.

The results of this project will make a major contribution to the development of high tech and well-fitted sportswear. They will allow a better selection of the fabrics as a function of comfort and compression.

Therefore, I would like to take the opportunity to thank VLAIO for their financial contribution to this project, the industrial project partners who supported us in the execution of the project, Simona Vasile, Benny Malengier and Joris Cools, the researchers who did a great job and last but not least Kirsten De Klerck, Celien De Bisschop (HOGENT) and UGent students who worked on this project in the framework of their thesis.

Alexandra De Raeve

29 November 2018

1. Introduction

Manufacturers of functional sports clothing lack extensive information about the body size and shape of their target group. Assays of the differences in body measurements compared to the average population are non-existent. Furthermore, information regarding the dimensional changes due to movement is limited. Therefore, the primary innovative objective of this project is to provide comprehensive information on body proportions and body postures and to develop a methodology to generate specific size tables and ditto patterns.

Secondly this project will foresee in adapted test protocols to gain a better insight in comfort and compression properties of elastic materials.

Finally virtual modelling was applied to evaluate the effect of compression garments and to investigate how hindering movement with textiles can be achieved.

2. Aim of the project

The main objective of SHAPE project Adapted Performance Sportswear was to develop comfortable, fitted and functional (sports)wear for elite sports athletes. To confirm the hypothesis that their body shapes and proportions differ significantly from the average population, it is imperative to analyze the anthropometric differences between the average population and various groups of athletes. In a next step this information must be translated into a methodology for garment development. In addition to a good fit wear comfort is also determined by the selected materials. Therefore adapted test protocols for testing comfort and compression characteristics of elastics fabrics were elaborated.

During the execution of SHAPE project the anthropometrics of elite cyclists and rowers were assessed. Two types of scanning techniques/principles were employed: 1) structured light 3D Body scanning by a state-of- the-art 3D body scanner and 2) photometry/photographing (i.e. measurements extracted from 2D pictures). Moreover, variation of body measurements and pressure upon (sport-specific) postures were investigated. As a result size charts were developed. Secondly a large collection of fabric for sportswear was tested for their comfort and functional properties. Since compression is considered to have an impact on muscle recovery and injury prevention virtual modelling was applied to evaluate the effect of compression garments and to investigate how hindering movement with textiles can be achieved. Finally several prototypes of sports gear for elite rowers and G-sport cyclists were designed and evaluated.

3. Materials

No materials were developed or purchased during the project. Nevertheless a large amount of fabrics were collected from the industrial partners participating in the project as listed below.

3.1 DECCA

- *Materials: n=2 fabrics, PES/ PP (outside/inside) untreated and treated (printed), 230 gsm.* Comfort properties were tested (details in Deliverable D4.1).
- Moreover *additional two fabrics* (PES/EL 86/14, 105 gsm and 130 gsm) were tested and used for production of hand biker prototypes (*Deliverable D5.2*).

3.2 BIORACER

- *Materials: n=2 fabrics, 64/36 PA/EL (TI 130 PES), 167 gsm and 75/25 (PES/EL), 136 gsm (ARCH-T Graphene).* Comfort and functional properties were assessed (details in Deliverable D4.1).
- Moreover *two additional materials* 62 PA/21 PES/17 EL, 245 gsm and 81 PES/19EL 155 gsm were tested and used for production of handbiker t-shirt prototypes (details in *Deliverable D5.2*) and *three fabrics* were used for the rowers sportswear prototype (*Deliverable D5.2*): 19 EL/81 PES 156 gsm, 76 PA/13 PES/11 EL, 156 gsm and 71 PA/29 EL, 147 gsm.

3.3 LIEBAERT

- *Materials: n=10, knitted PA/elastane fabrics, 135-270 g/gsm.* Comfort properties were tested (details in Deliverable D4.1).

3.4 DECATHLON

- *Materials: 51 fabrics for sportswear.* Fabric hand was assessed on two sides, according to Fabric Touch tester (FTT).

3.5 ELASTA

- *Materials:* n=6 bands braided and woven, 4 to 14mm wide (2017). Young Modulus was tested to determine their suitability for use in injury protecting garments
- *Materials:* n=5 non elastic knitted PES/PES and braided bands CO 50/2x2 (2018). Young Modulus was tested to evaluate best use.

Samples of the materials used are collected in a swatches book.

4. Methods

4.1 FABRIC TESTING

Comfort and functional tests were carried out on fabric-level according to the test methods listed below:

- air permeability (ISO 9237-1995): no stretch/ biaxial stretch
- water vapour permeability (ISO 15496:2015)
- moisture management MMT (AATCC 195:2011)
- fabric hand (Fabric Touch Tester FTT)
- moisture drying rate and time (ISO 17617:2014): acid/alkaline artificial sweat
- waterproofness (hydrostatic pressure test, ISO/DIS 811:2016
- influence of domestic washing (ISO 6330:2012) on various fabric properties as above
- pressure exerted by a fabric on a plastic cylinder (% stretch), by Picopress

Testing devices employed are shown in Figure 1 and details about each test method are provided in Deliverable D4.1.

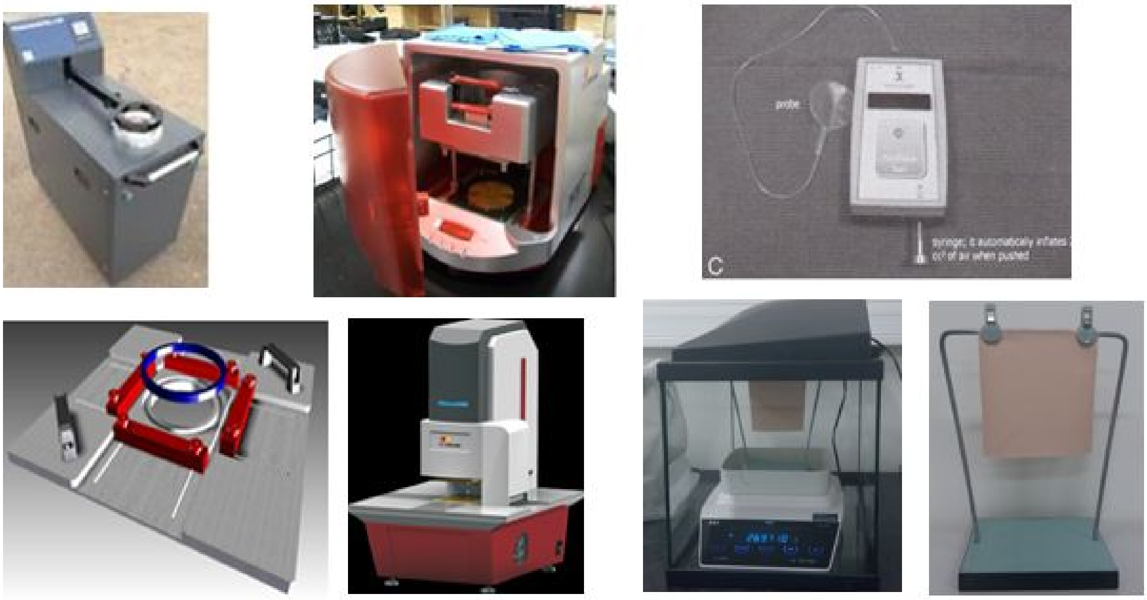


Figure 1 Instruments for quantitative assessment of fabric-comfort related properties

4.2 TESTS PROTOCOLS FOR ASSESSMENTS OF ANTHROPOMETRICS OF ROWERS AND CYCLISTS

4.2.1 Target groups

The first target group consisted of male (M) and female (F) *elite rowers* (sculling and sweep) of age 18-35 Y, divided in the following categories: (1) M/F light-weight (LW) of maximum 72.5 kg/59 kg and (2) M/F heavy weight (HW) of maximum of 90 kg/ 75 kg.
The second target group consisted of *cyclists* in different disciplines (track, sprint, triathlon, road, BMX) were targeted, divided in three categories: (1) juniors M/F of 17-18 Years, (2) U23 M/F of 19-22 Y and (3) Elite (M/F) of 23-25 Y.

To allow reliable statistical processing of the results, the dataset was set on about 100 athletes of each of the two disciplines. The recruitment of the subjects was done via the project website (http://www.shape-project.be/) as well as via the Flemish rowing/ cycling federations and individual approaches of the sport clubs. The response was low and only few measurements were done at location of HOGENT-FTILab. Therefore it was decided to conduct the measurements during rowing and cycling contests, on different locations. Measurements of rowers were taken during Belgian Championship BC (September 2017, Sport Vlaanderen Willebroek), International Rowing Regatta (Gent, May 2018) and the measurement of the cyclists was done during indoor Belgian Championship BC (Gent, December 2017).

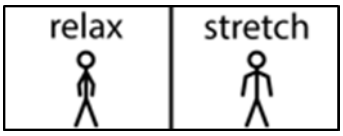
Finally, a total *74 rowers (54 male and 20 female) and 14 cyclists (11 male and 3 female)* were measured by different scanning techniques, in static and dynamic sport postures (see details in chapter 4.2.2). The cyclists dataset was too limited and only for a limited number of statistical analysis could be applied.

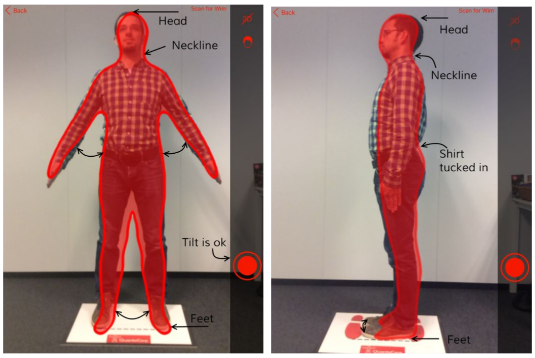
4.2.2 Scanning protocol

The measuring techniques used to assess body measurements in various sport postures are summarized in Table 1 below.

Table 1 Body measurements, postures and related equipment

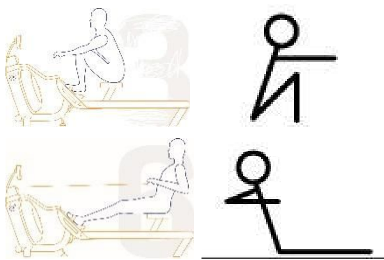
Equipment	Body measurements and sport posture
Anthropometer KERN MPB-P 	body weight and height

<table>
<tr><td>3D body scanners with structured light technology: (Symcad ST and TC2 NX16)
</td><td colspan="2">~# 30 1D body measurements cf. ISO 8559-1989
2D measurements cf. ISO 8559-1989
3D point cloud of the subjects</td></tr>
<tr><td></td><td colspan="2">ic postures: A-pose relaxed and tensed (stretch)


during testing, all the subjects wore a white test suit as shown below in the table.</td></tr>
<tr><td>QuantaCorp mobile scanner (2D photometry)
</td><td colspan="2">2 static postures x 2 photo's: 1D measurements (# 22) and # 1 3D measurements (volume of whole body)


Note: all the subjects wore a white test suit as shown below in the table.</td></tr>
<tr><td>ing tape

eter Concept 2

stening system Tack Cycleforce Flow
</td><td colspan="2">l-taken body measurements: back length, across back width, waist girth, upper-arm girth, thigh girth, knee girth (ISO 8559-1989)</td></tr>
<tr><td></td><td>Postures rowers: catch and finish
</td><td>Postures cyclists: foot up/ down

</td></tr>
<tr><td>ss: max 189 mmHg (~25 KPa)</td><td colspan="2">upper-arm and mid-thigh Pressure (mmHg) exerted by the test suit on upper-arm and mid-thigh</td></tr>
</table>

4.3 VIRTUAL MODELLING

Virtual modelling was applied to evaluate the effect of compression garments and to investigate how movement hindering can be achieved with textiles. Four possibilities were evaluated:

- First order approximations of forces based on the elastic properties of fabrics
- Application of OpenSim, a powerful tool for modelling movement of NCSRR, for the development of garments and ortheses
- Application of DySiFil, a custom fast filament simulator of UGent, to obtain fast and reliable garment pressure information, with the option of dynamic movement.
- Application of Abaqus, an FEM engineering analysis tool of Simulia, to obtain accurate fabric deformation simulations.

5. Results

5.1 LIST OF AVAILABLE PUBLIC DELIVERABLES

The deliverable of project SHAPE with a brief summary of their content are listed in Table 2 bellow.

Table 2 List of available deliverable

	Title	Type	Content
D1.1	State of the art	Report	State of the art including studies about anthropometrics of rowers and cyclists, compression sportswear, materials for high active sportswear, Body Mapped Sportswear (BMSs) and biomechanical models (Report, 35 pages).
D1.2	Noden en problemen van eindgebruikers (NL)	Report	Problems and requirements for clothing for handbikers and rowers (established via interviews) and gloves to prevent injuries in fight sports/ martial arts (Report, 12 pages).
D2.1	Dataset of body measurements of elite rowers and cyclists	Report Datasets	Info about the target groups and scanning protocol. Brief summary of demographics for a total of 74 M/F rowers and 14 M/F cyclists (Report, 7 pages).
D2.2	Post processing avatars	Report Avatars	Reconstruction of an 3D point cloud, prediction (software UAntwerp) and comparison of the avatar constructed starting from 12 body measurements extracted from 3D scans and 2D pictures (Report, 9 pages).
D2.3	PCA analysis id dataset rowers and cyclists	Report	PCA analysis applied to the dataset of rowers and identification of the main body measurements that characterize the anthropometry of the two target groups.
D2.4	Variation of body measurements with sport-specific posture	Report	Differences between several body measurements taken manually & clothing-body interface pressure, in static and two dynamic sport postures. Discussion of static vs. posture body measurements in garment patterning of stretch garments (Report, 13 pages).
D2.5	Body measurements of Belgian male (BM) and heavy weight male rowers (HWMR)	Report	Results with (statistical significant) differences between 22 body measurements of BM and HWMR, taken by 3D scanning, in A-pose, based on a dataset of 35 HWMR and 83 BM (Report, 9 pages).

D2.6	Comparison of selected body measurements of rowers extracted from 2D (QuantaCorp photometry) and 3D (3D body scanning)	Report	Two technologies were used (2D photometry and 3D body scanning) and several body measurements (#23) of # 55 elite rowers were extracted. This report (11 pages) contains a comparison of the body measurements taken by the two technologies, aiming at assessing the suitability of 2D technology for the purpose of (tight) garment patterning.
D2.7	Average avatars heavy weight male rowers	Report, Avatars (stl, obj)	The average body sizes of heavy weight rowers (HWMR), garment size 54 were extracted from 3D scans. Open source software *Make Humans* was used to generate the avatars. This report (7 pages) contains comparison of avatars of HWMR and BM of same garment size.
D3.1	Knowledge building on stimulating or hindering body movements	Report	Within 3 domains (cycling, rowing, hand injury fighting sports) an investigation is done to determine what type of body movements should be stimulated, and in what case hindering movement is beneficial.
D3.2	Properties of textile materials to achieve the functionality	Report	Based on the needs, the required properties of textile material to stimulate or hinder body movement are identified.
D3.3	Virtual simulation environment for engineering compression clothing and ortheses	Model	A workflow is developed with Abaqus and DySiFil to investigate compression materials virtually. A work plan is made how OpenSim could be adapted for orthoses.
D4.1-4.3	Comfort and functional testing of fabrics for sportswear	Summary Report Swatch book	This report (10 pages) contains a summary of materials from industrial partners and description of the tests methods.
D5.1	Body size charts for heavy weight male rowers (HWMR)	Body size chart; report	This report (4 pages) contains the size charts for HWMR developed based on a dataset of 52 subjects.
D5.2	Case studies	Report; 4 prototypes	This report includes details about 12 case studies with involvement of industrial partners.
D6.1-D6.4	Dissemination activities	Report	This report (6 pages) contain a list of various kind of dissemination activities.

5.2 ANTHROPOMETRY OF HEAVY WEIGH MALE ROWERS VERSUS BELGIAN MALE POPULATION

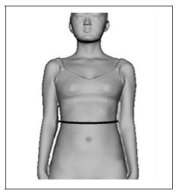
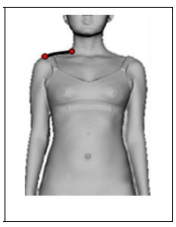
A total number of *35 heavy weight male rowers (HWMR*) were measured in *A-pose* during project SHAPE via 3D body scanning technology and *22 body measurements* were extracted. Their body measurements and three additional body ratio' s were subsequently compared with those of average Belgian man (BM) of similar mean age (23). The dataset of BM was set up during measuring campaign of Belgian population (2013-2014, project SMARTFIT). The demographics of BM and HWMR are shown in Table 3 below and the 22 body measurements extracted (ISO 8559-1 (2017) and the 3 ratios calculated (chest/waist, chest/hip and waist/hip) are displayed in Table 4.

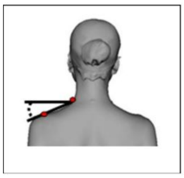
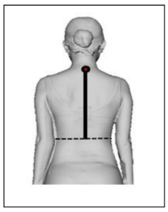
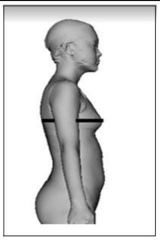
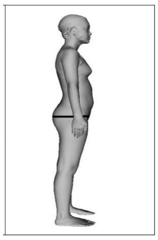
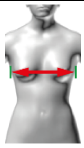
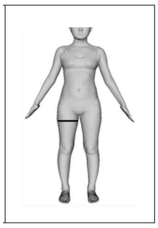
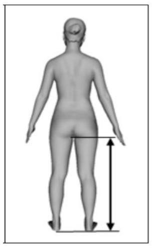
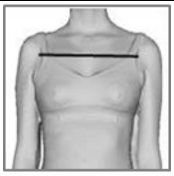
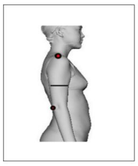
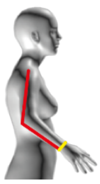
Table 3 Average demographics of HWMR and BM

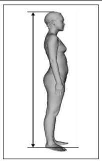
	Belgian male (BM)				**Heavy weigh male rower (HWMR)**			
	mean± stdev	median	min	max	mean± stdev	median	min	max
N	83				35			
Age (Y)	24±4	23	18	30	21±2,5	20	18	30
Height (cm)	181,1±6,4	180,8	167,5	196	185,5±5,3	186,3	172,	198,1
Weight (kg)	80,7±6,2	79,3	72,5	99.4	83,6±8	84,1	72,7	99,8
BMI	24,8±2,5	24,4	20,2	34,0	24,1±1,8	24	19,9	29,2

Note: mean values for rowers are based on total number of rowers regardless their country of origin

Table 4 Anthropometric definitions for body measurements

	Body measurements (EN/NL)			**Body measurements (EN/NL)**	
1	Neck girth (Halsomtrek)		12	Waist girth (Tailleomtrek)	
2	Shoulder length (Schouderlengte)		13	Upper hip girth (Tailleomtrek navel)	

3	Shoulder slope (Shouderdaling)		14	Back neck point to waist (Ruglengte tot taille)	
4	Chest girth (Borstomtrek)		15	Hip girth (Heupomtrek)	
5	Chest width (Borstwijdte)[+]		16	Thigh girth (Dijbeenomtrek)	
6	Across back width (Carrure rug)		17	Inside leg length (Binnenbeenlengte)	
7	Across front width (Carrure voor)		18	Knee girth (Knieomtrek)	
8	Upper-arm girth (Bicepsomtrek)		19	Lower knee girth (Onderknieomtrek)	
9	Arm length[++] (Armlengte)		20	Calf girth (Kuitomtrek)	
10	Wrist girth (Polsomtrek)		21	Ankle girth (Enkelomtrek)	

11	Stature (Lengte)	
22	Weight (Gewicht)	23. Ratio chest/ waist (Borst/ Taille)
24	Ratio waist/ hip (Taille/ Heup)	25. Ratio chest/ hip (Borst/ Heup)

[+] No correspondence with ISO 8589-2016; Symcad; [++]ISO 8559-1989

Significant differences between the target groups

The absolute differences (cm) between HWMR and BM for the variables considered are shown in the Figure 2 bellow. Bars in red indicate a statistically significant difference ($p<0.05$). For the considered dataset, there are 13 significant differences in the body measurements of rowers and average Belgian man, especially the chest girth and stature (rowers > 4 cm larger than Belgian males).

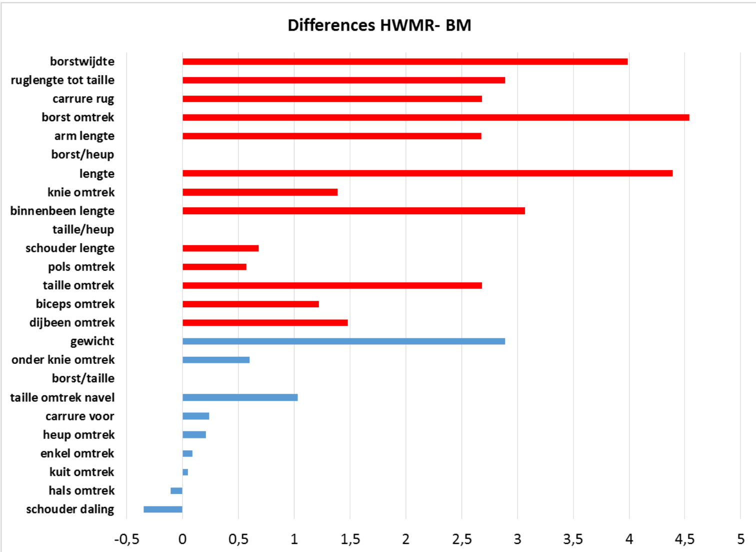


Figure 2 Absolute differences (cm) between HWMR and BM

The T-ratio difference HWMR- BM for the variables considered are shown in the Figure 3 bellow. Bars in red indicate a statistically significant difference ($p<0.05$). T-ratio difference = |difference|/SE(difference), where SE is Standard Error SE = SD/$\sqrt{}$(sample size). A HWMR-BM T-ratio difference higher than 0 indicates that the rowers have larger body measurements than the average male. For instance, chest width of the rowers is significantly larger as compared with the average Belgian male (T-ratio 10). On contrary, the Belgian males have larger neck girth (T-ratio -0.3) and shoulder slope (T-ratio -1.5) than the rowers, but the difference is not significant.

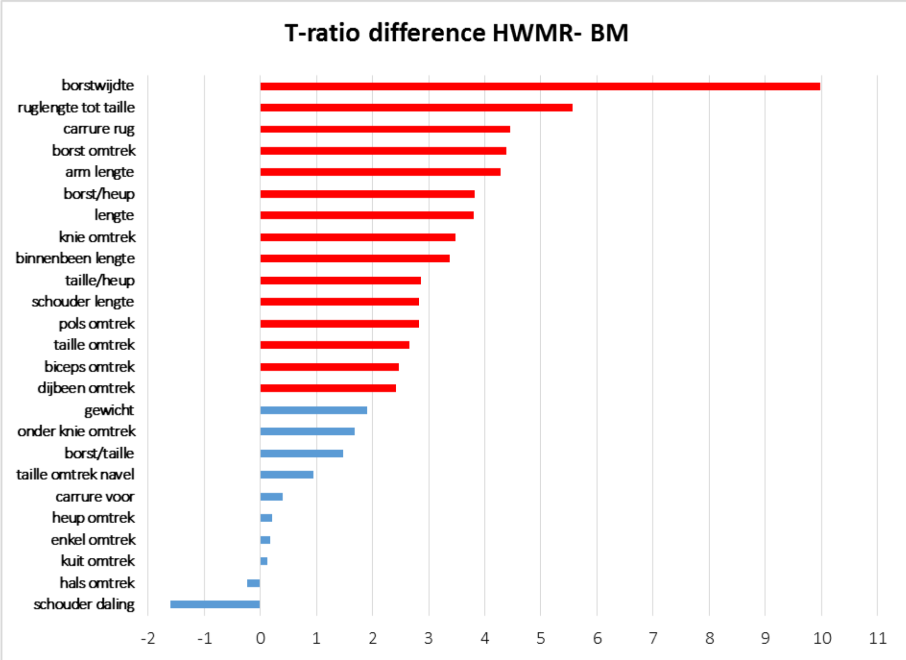


Figure 3 T-ration HWMR-BM

The ratio of the coefficients of variation CV (CV HWMR/ CV BM) is shown in Figure 4 below. Two body measurements of the rowers (shoulder length and shoulder slope) have a significant higher variability as compared with average Belgian male and three of the considered variables have significant lower variation (as indicated by the red lines).

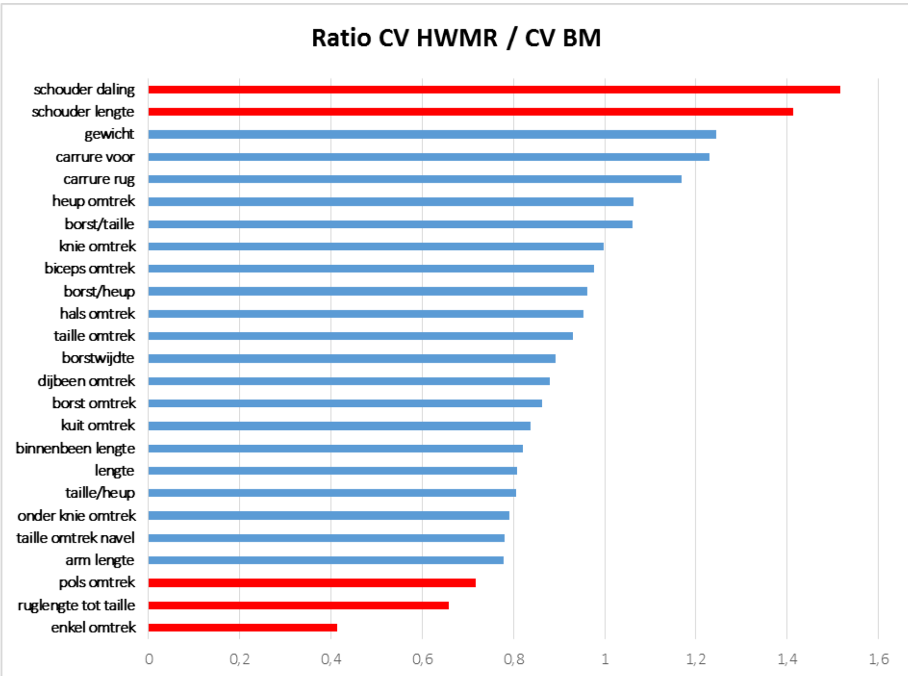


Figure 4 Ratio CV HWMR/ CV BM

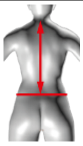
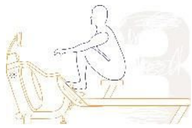
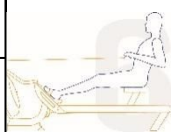
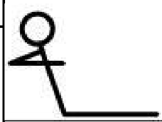
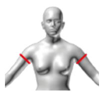
In conclusion, for the considered dataset, 13 significant differences ($p<0.05$) were found between the body measurements of rowers and average Belgian man, especially with respect to the chest girth and stature (rowers > 4 cm larger than Belgian males). Length of chest, back, legs, was also significant larger (up to 4 cm) for the rowers, similarly to several body girths among which waist, upper-arm, thigh and knee.

Although quite limited in terms of number of rowers (about 20 % of total), this study clearly identified significant body measurement differences between the two target groups. These findings are important for the garment industry. To ensure a perfect fit, casual and sportswear for the rowers should be made starting from size charts based on average body measurements found (Deliverable 5.1).

5. 3 INFLUENCE OF SPORT POSTURE ON ANTHROPOMETRY OF ROWERS AND CYCLISTS

The target group for this analysis consists in male (M) and female (F) elite rowers (sculling and sweep) of age 18-35 Y, divided in two categories: (*a*) *light-weight M/F: max. 72.5 kg/59 kg and (b) heavy weight M/F: max. 90 kg/ 75 kg.* Cyclists in different disciplines (track, sprint, triathlon, road, BMX) were targeted, *divided in age-categories: M/F Juniors (17-18 Y); U23 (19-22 Y); Elite (23-25 Y). Five body measurements* were measured manually for a total number of *74 rowers (54 male and 20 females)* in *static and two dynamic postures (catch and finish*). Moreover the *pressure exerted by the sport suit at two body locations (upper-arm and thigh)* was measured instrumentally in the same static and dynamic postures (Table 5). Similarly the influence of *posture (knee up/knee down)* on same anthropometrics and pressures was assessed for N=*11 male cyclists*.

Table 5 Body and pressure measurement at various body areas and postures

Body measurements		Posture	Instrument
Back length (measured on black line on the test suit)	 	1. Static (rowers and cyclists)  2. Dynamic 2.1 Catch (rowers)   2.2 Finish (rowers)   2.3 Foot upper most	Measuring tape 
Back width (measured on the test suit)			
Waist girth (ISO 8559-2016)			
Thigh (ISO 8559-2016)			
Upper-arm girth (ISO 8559-2016)			
Knee girth (ISO 8559-2016)			
Pressure test suit-body (on biceps and mid tight)			ss 

		2.4 Foot upper down (cyclists) tuck 	

A total of # 74 rowers from different countries (Table 6) were measured with the averages demographics as shown in Table 7.

Table 6 Total number of elite rowers by category, gender and origin

	Algeria	Cyprus	UK	Ireland	Portugal	Tunisia	Belgium	Total
Male (M)	**2**	**2**	**6**	**7**	**4**	**1**	**32**	**54**
Light-weight LW (max. 72.5 kg)	1	1	-	5	-	-	6	13
Heavy weight HW (max. 90 kg)	1	1	6	2	4	1	26	41
Female (F)	**2**			**2**		**2**	**14**	**20**
Light-weight LW (max. 59 kg)	2	-	-		-	1	4	7
Heavy weight HW (max. 75 kg)	-	-	-	2	-	1	10	13
Total number N	**4**	**2**	**6**	**9**	**4**	**3**	**46**	**74**

Table 7 Demographic characteristics of M/F rowers

	Male (M)				**Female (F)**			
	Mean±Stdev	median	min	max	Mean± Stdev	median	min	max
N (LW/HW)	54^{+} (13/41)	- -	- -	- -	20^{++} (7/13)	- -	- -	- -
Age (y)	21 ± 4	20	17	35	20.8±7	19	15	44
Height (cm)	183.6±6.8	184,1	171,4	205	170,2±4,4	169,9	163,7	179,0
Weight (kg)	80,5±9,2	79,2	62,9	99,8	64,7±7,6	63,3	54	84,5
BMI	23,8±1,9	23,7	19,9	29,2	22,3±2,5	22	19,3	29,5

LW-low weight, HW-heavy weight, $^{+}$ # 32 Belgium, # 6 UK, # 4Portugal, # 1Tunisie, # 1 Ireland; # 7 Cyprus; # 2 Algeria; $^{++}$ # 14 Belgium, # 2Tunisia, # 2 Ireland; # 2 Algeria;

Male rowers: variation of selected anthropometrics and pressure with rowing dynamic postures

In Table 8 the mean body measurements and pressure of the dataset male rowers in static and two sport positions are listed and graphically displayed in Figure 5 and 6. Significant difference of body measurements and pressure between catch-static-and finish-static posture are shown in Table 9 and changes (%) displayed in Figure 7.

Table 8 Male rowers: mean anthropometrics and pressure in static and two dynamic postures (catch and finish)

	Upper-arm girth (cm)	Thigh girth (cm)	Knee girth⁺ (cm)	Back length⁺⁺ (cm)	Back width⁺⁺⁺ (cm)	Pressure upper-arm (mmHg)	Pressure thigh⁺⁺⁺⁺ (mmHg)
Static	30,2±1,9	59,5±3,9	44,6±4,4	49,9±2,4	39,6±2,6	3±2	7±2
Catch	29,8 ±1,7	58,5±3,7	47,4 ±3,4	56±2,9	46,1±4,1	4±3	10±2
Finish	33,5 ±2,3	60.1 ±3,4	44,1±4,3	52,2±2,4	36,2±3,5	5±2	7±2

⁺ knee girth measured above the knee; ⁺⁺ measured on the sport suit (black line); ⁺⁺⁺ measured on the suit; ⁺⁺⁺⁺ measured in front, above the knee support fabric

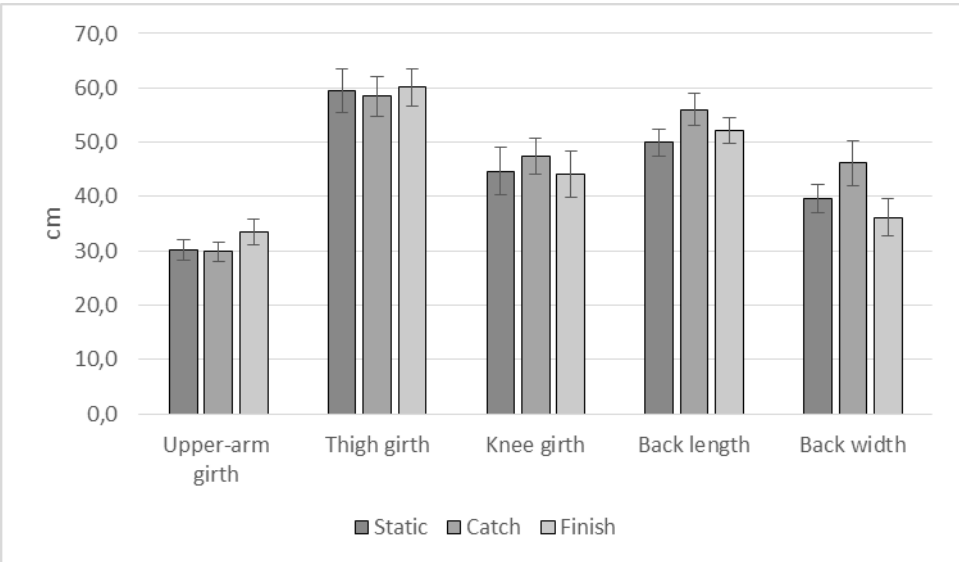


Figure 5 Male rowers: mean anthropometrics in static and two dynamic postures

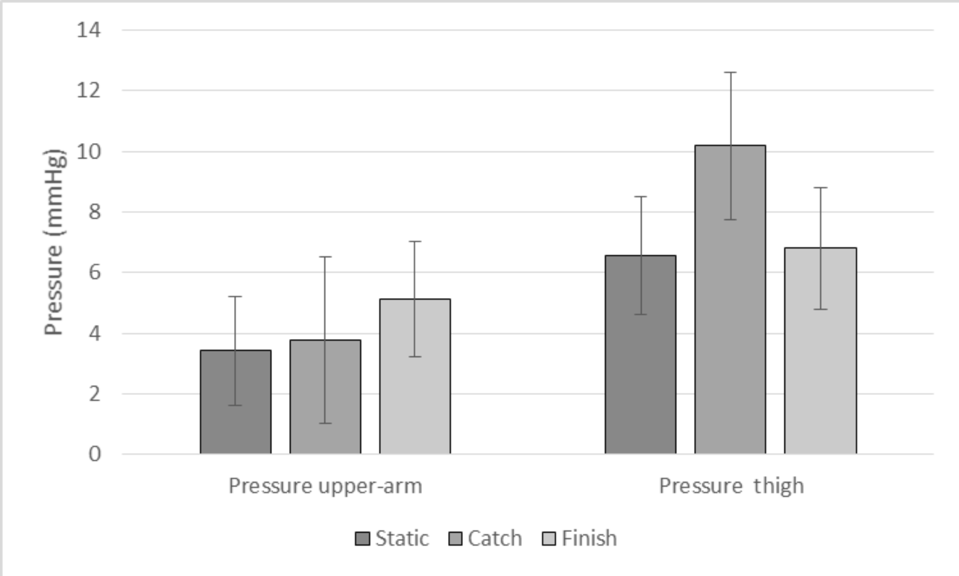
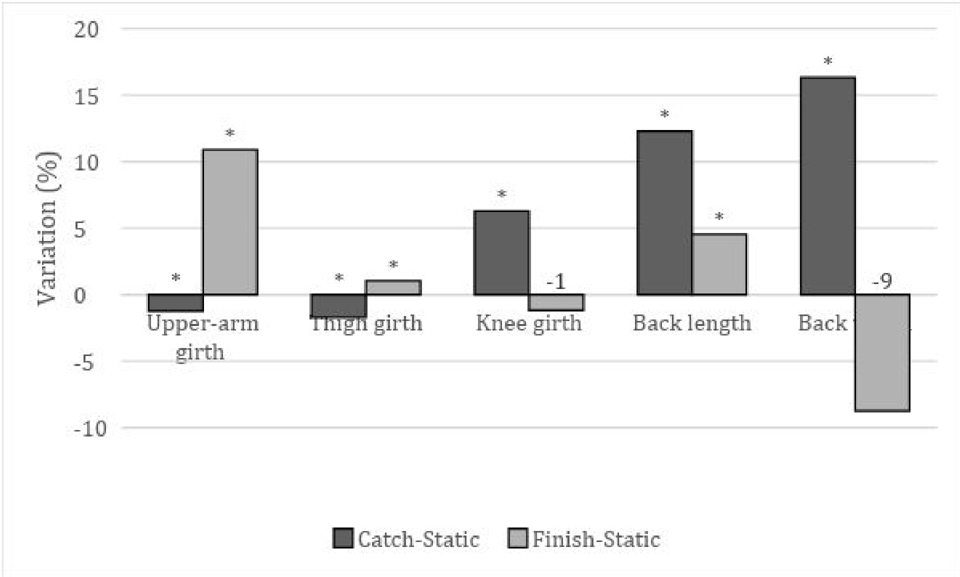


Figure 6 Male rowers: mean pressure in static and two dynamic postures (catch and finish)

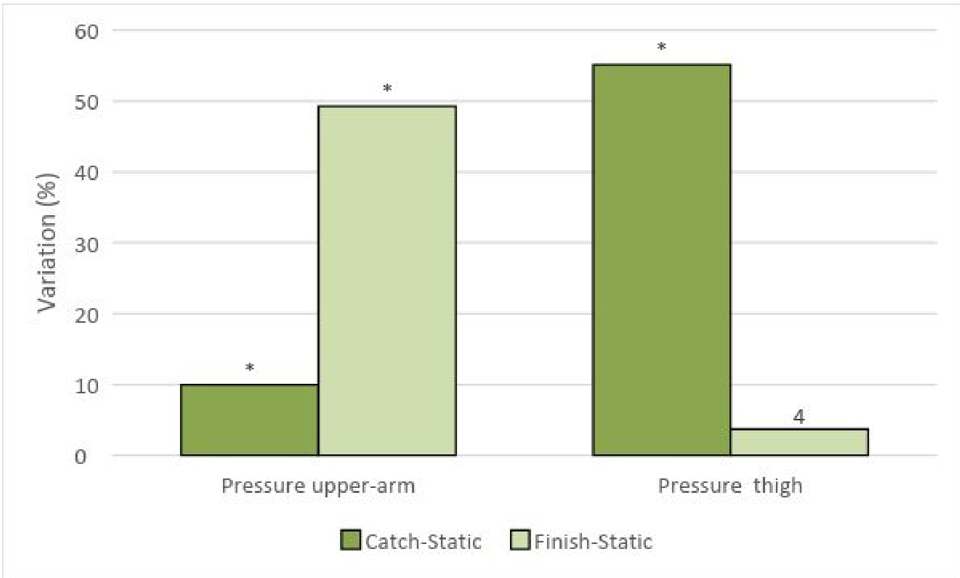
Table 9 Male rowers: variation of anthropometrics and pressure with dynamic postures

	Catch-Static		Finish-Static	
	difference	p-value	difference	p-value
Upper-arm girth (cm)	**-0,4***	p<0,01	**3,3***	p<0,01
Thigh girth (cm)	**-1***	p<0,01	**0,6***	p<0,01
Knee girth (cm)	**2,8***	p<0,01	-0,5	p=0,2
Back length (cm)	**6,1***	p<0,01	**2,3***	p<0,01
Back width (cm) $^{+}$	**6,5***	p<0,01	**-3,5***	p<0,01
Pressure upper-arm (mmHg) $^{++}$	0	p=0,15	**2***	p<0,01
Pressure thigh (mmHg) $^{+++}$	**4***	p<0,01	0	p=0,3

*paired t-test, significant differences (p<0.01); N=54 subjects for girth upper-arms/thigh/knee and back length; $^{+}$ measured for N=22 subjects; $^{++}$ measured for N=38 subjects; $^{+++}$ measured on N=37 subjects.



(a)



(b)

Figure 7 Male rowers: relative variation (%) static-dynamic posture of (a) selected anthropometrics and (b) pressure on upper-arm and thigh

Female rowers: variation of selected anthropometrics and pressure with rowing dynamic postures

The average anthropometrics of the female rowers and pressure measured at two body locations are shown in Table 10 and Figures 8 and 9.

Table 10 Female rowers: average anthropometrics and pressure

	Upper-arm girth (cm)	Thigh girth (cm)	Knee girth[+] (cm)	Back length[++] (cm)	Back width[+++] (cm)	Pressure upper-arm (mmHg)	Pressure thigh[++++] (mmHg)
Static	27±2,1	58,7 ±5,8	41,9±3,7	45,9±1,6	34,7±2,2	3±1	6±1
Catch	27,2±2,7	57,3±5,4	44,9±3,6	50,8±3,4	39,4±3,1	3±1	10±3
Finish	29,3±2,5	59±4,6	41,1±3,9	47,6±2	32,3±2,9	4±2	6±2

[+] knee girth measured above the knee xxx; [++] measured on the sport suit (black line); [+++] measured on the suit; [++++] measured in front, above the knee support fabric.

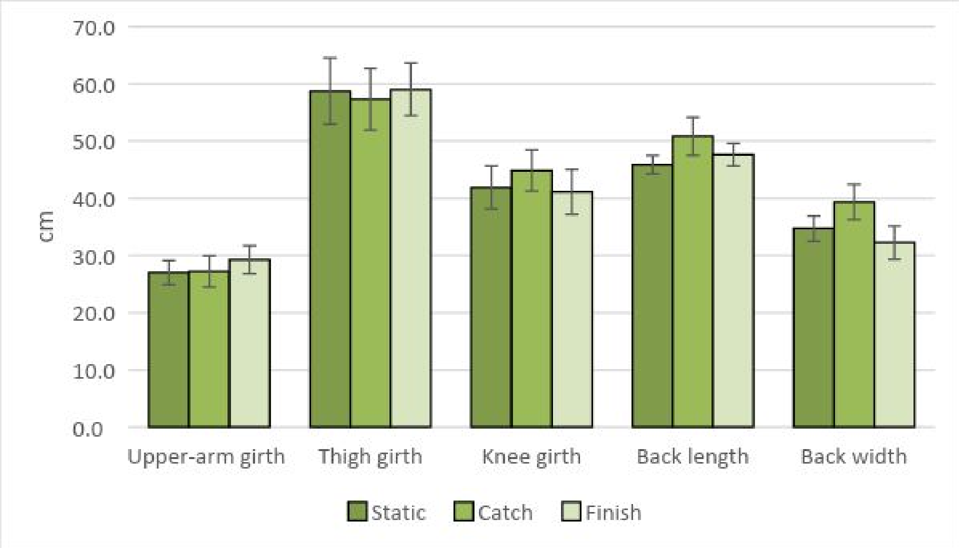


Figure 8 Female rowers: mean anthropometrics in static and two dynamic postures

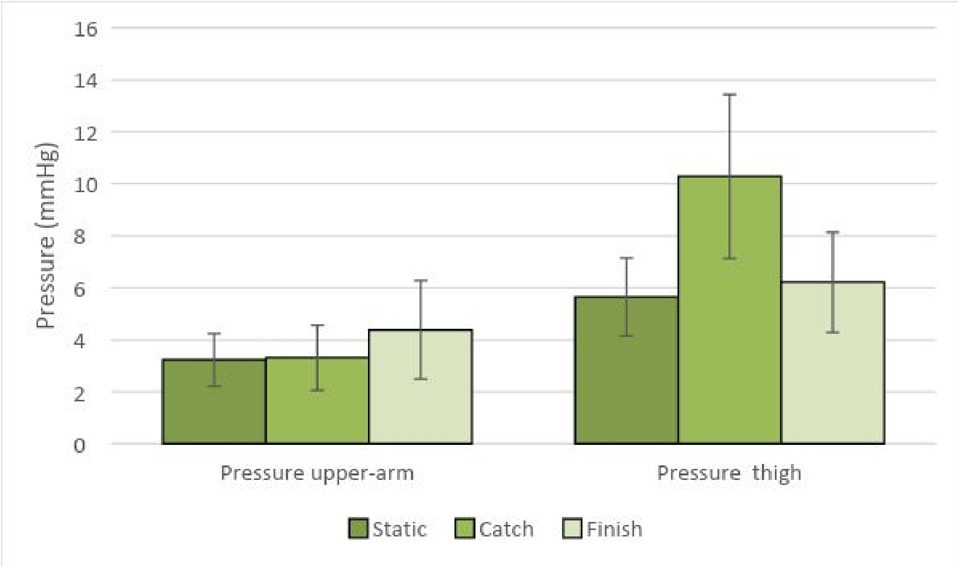


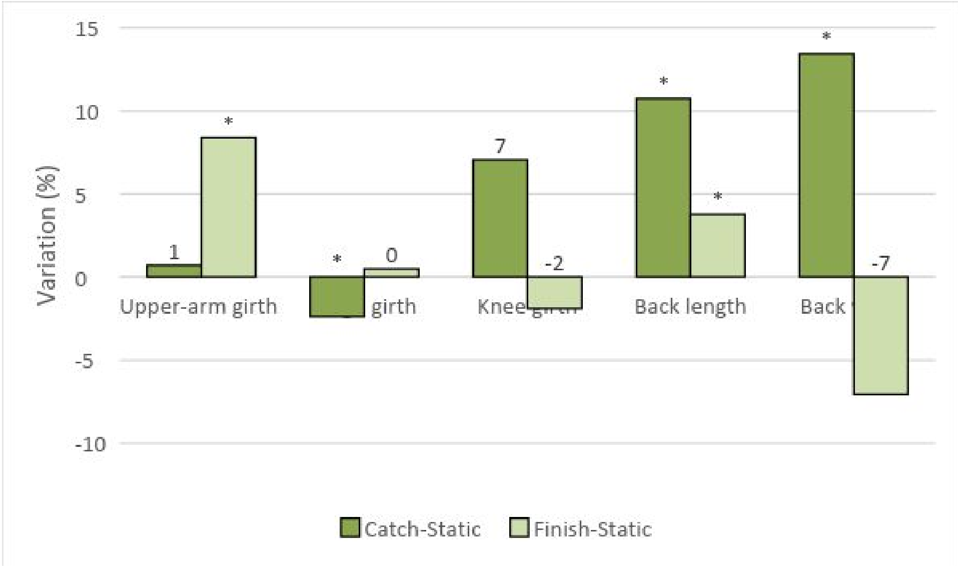
Figure 9 Female rowers: mean pressure in static and two dynamic postures (catch and finish)

Significant difference of body measurements and pressure between static-catch posture and static-finish posture are shown in Table 11 and changes (%) displayed in Figure 10.

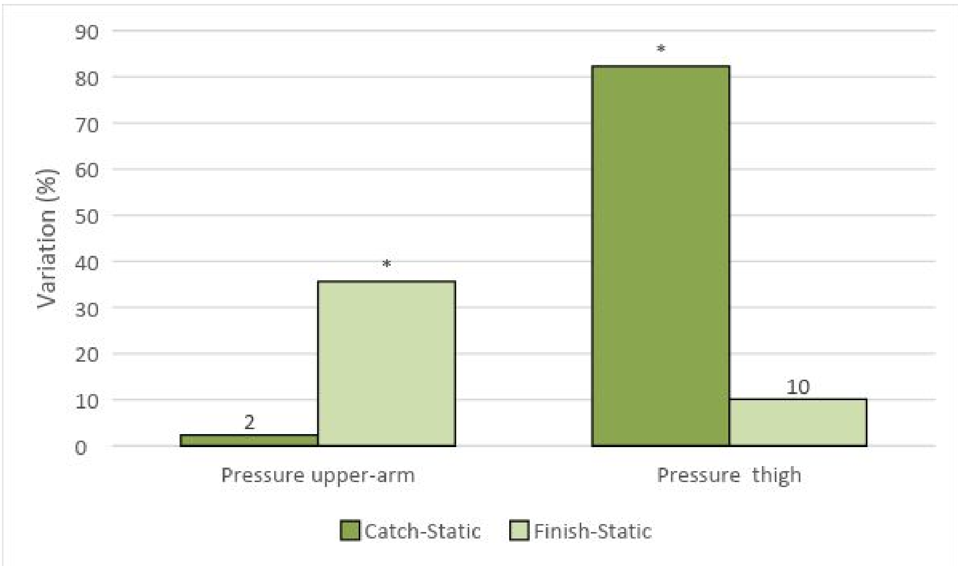
Table 11 Female rowers: variation of anthropometrics and pressure with dynamic postures

	Catch-Static		Finish-Static	
	difference	p-value	difference	p-value
Upper-arm girth (cm)	0,2	p=0,5	**2,3***	p<0,01
Tight girth (cm)	**-1,***	p= 0,01	0,3	p=0,7
Knee girth (cm)	2,9	p=0,02	-0,8	p=0,5
Back length (cm)	**4,9***	p<0,01	**1,7***	p<0,01
Back width (cm) +	**4,7***	p<0,01	-2,5	p=0,1
Pressure upper-arm (mmHg) ++	0	p=0,6	**1***	p<0,01
Pressure thigh (mmHg) +++	**5***	p<0,01	1	p=0,17

*paired t-test, significant differences (p<0.01); N=20 for girth upper-arm/tight/knee and back length; + measured for N=6 subjects; ++ measured for N=13 subjects; +++ measured on N=14 subjects



(a)



(b)

Figure 10 Female rowers: relative variation (%) static-dynamic posture of (a) selected anthropometrics and (b) pressure on upper-arm and thigh

Cyclists

A total of # 14 cyclists (17-32 Y) were measured belonging to different categories, as shown in Table 12 below and the subject's demographics are given in Table 13.

Table 12 Total number of elite Belgian cyclists measured according to their category and gender

Gender / Category	Track	Sprint	Triathlon	Road	Total
Male	**10**		**1**		**11**
Belofte (19-22)	7				7
Elite (23-35Y)	2				2
Junior (17-18Y)	1				1
No prof			1		1
Female	**1**	**1**		**1**	**3**
Belofte 19-22)	1	1			2
Elite (23-35Y)				1	1
Total number N	**11**	**1**	**1**	**1**	**14**

Table 13 Demographics of Belgian M/F cyclists

	Male (M)				**Female (F)**			
	mean± stdev	median	min	max	mean± stdev	median	min	max
N (track/triathlon/road)	11 (10/ 1/ 0)				3 (2/0/1)			
Age (Y)	21,6± 4,8	19	17	32	22± 1	22	21	23
Height (cm)	179,8 ±4,9	179	171,8	191,.6	169,8± 4,8	170	165	174,5
Weight (kg)	75± 5,9	74,7	64,3	84,1	70,7± 7,3	70,1	63,7	78,2
BMI	23,2± 2,1	23,2	20,3	26,4	24,6± 3,9	24,3	20,9	28,7

Male cyclists: Variation of selected anthropometrics and pressure with cycling dynamic postures

The mean anthropometrics of the dataset and the pressure measured at two body locations are shown in Table 14, Figure 11 and 12 for static and two dynamic postures.

Table 14 Male cyclists: mean anthropometrics and pressure in static and two dynamic postures (knee up, knee down)

	Upper-arm girth	Tight girth (cm)	Knee girth[1] (cm)	Back length[2] (cm)	Back width[3] (cm)	Pressure upper-arm	Pressure thigh[4] (mmHg)

	(cm)					(mmHg)	
Static	29,3± 2,5	58,6±3,3	43,4±2,7	48,6±1,2	37,7±1,5	4±1	7±2
Knee up	28,7±2	56,9±3,1	43,2±3	53,6±1,7	41,8±2,1	4±1	10±2
Knee down	-	57,9±3,8	42,3±2,8	-	-	-	8±1

[1] knee girth measured above the knee; [2] measured on the sport suit (black line); [3]measured on the suit; [4] measured in front, above the knee support fabric; N=11 subjects

Figure 11 Male cyclists: mean anthropometrics in static and two dynamic postures

Figure 12 Male cyclists: mean pressure in static and two dynamic postures

Significance difference of body measurements and pressure between knee-up and static posture and knee down-static posture are shown in Table 15 and changes (%) displayed in Figure 13.

Table 15 Male cyclists: variation of anthropometrics and pressure with dynamic postures

	Knee up- Static		Knee down -Static	
	difference	p-value	difference	p-value
Upper-arm girth (cm)	-0,5	p=0,54	-	-
Thigh girth (cm)	**-1,7***	p<0,01	-0,7	p=0,62
Knee girth (cm)	-0,2	p=0,88	-1	p=0,39
Back length (cm)	**5***	p<0,01	-	-
Back width (cm)	**8,1***	p<0,01	-	-
Pressure upper-arm (mmHg)	-1	p=0,27	-	-
Pressure thigh (mmHg)	**2***	p=0,01	-	-

*paired t-test, significant differences (p<0.01)

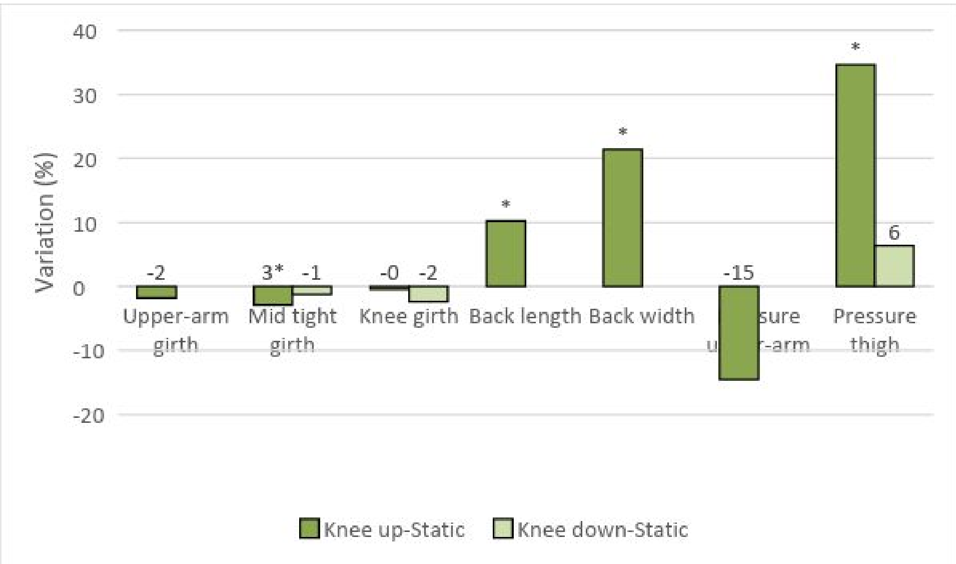


Figure 13 Male cyclists: relative variation (%) static-dynamic posture of selected anthropometrics and pressure on upper-arm and thigh

Female cyclists: The data set was too small therefore the influence of posture on anthropometrics and pressure was not investigated.

Conclusions male rowers:

- In general, it seems that posture led to more influence on pressure than on anthropometrics. For instance, posture led to a change of anthropometrics and pressure of up to 16%, respectively 55%. *Back length and width are most affected by posture, which increased especially in catch position: 12% (6.1 cm) and 16% (6.5 cm) respectively*

- Most of the changes posture-static were *statistically significant (alfa= 0.01)*:
  - Finish posture: *increase of upper-arm girth (11%), thigh girth (1%), back length (5%) and pressure on upper-arm (49%)*
  - Catch posture: *increase of knee girth (6%), back length (12%), back width (16%),* pressure on upper-arm (10%), pressure on thigh (55%) and *decrease of upper-arm girth (-1%) and thigh girth (-2%).*
- The pressure increased largely with the posture but the absolute values of maximum 10 mmHg indicate a low pressure and thus adequate garment pressure comfort.

Conclusions female rowers:

- Similarly to male rowers, posture led to more changes in pressure than in anthropometrics, 13% versus 82%. *Back length and width were most affected by posture, which increased especially in catch position: 11% (4.9 cm) and 13% (4.7 cm)* respectively. This is similar to male rowers, but the amplitude is lower.
- Most of the changes posture versus static were statistically significant:
  - Finish posture: *increase of upper-arm girth (8%), back length (4%) and pressure on upper-arm (36%);*
  - Catch posture: *back length (11%), back width (13%),* pressure on thigh (82%) and *decrease of thigh girth (-2%).*
- The pressure increased largely with the posture but the absolute values of maximum 10 mmHg indicate a low pressure and thus adequate garment pressure comfort.

Conclusions male cyclists:

- The dataset of cyclists was low (N=11), but as for the rowers, the posture led to more influence on pressure than anthropometrics, 21% versus 35%. *Back length and width are most affected by posture, which increased in knee-up posture with 10 % (5 cm) and 21% (8.1 cm) respectively.*
- Only some changes statistically significant in knee-up- static posture: *increase of back length (10%), back width (21%) and pressure on thigh (35%) and decrease of thigh girth by 3%.*
- The pressure increased largely with the posture but the absolute values of maximum 10 mmHg indicate a low pressure and thus adequate garment pressure comfort.

In case of elastic sportswear, it is argued that fabric elasticity will accommodate the body changes induced by the posture and therefore no further allowance should be added to the garment pattern. However, this assumption should be validated by prototypes, especially in case of casual garment and low-elasticity fabrics.

5.4 BODY SIZE CHARTS OF HEAVY WEIGHT MALE ROWERS

This deliverable is related to *WP5, Task 5.1.* The body measurement of male and female rowers of different categories were taken by 3D body scanning in A-pose. The dataset of female rowers consisted of a total of 20 subjects of which N=7 low weigh (LW) and N=13 heavy weight (HW). The dataset of male rowers considered of 54 rowers of which N=13 LW and N=41 HW. Body size charts were generated only for the HW male rowers as the number of subjects for other categories was too low.

Chest girth is defined as the primary dimension for full bodies according ISO 8559-2:2017 (Size designation of clothes - Part 2: Primary and secondary dimension indicators). The subjects were categorized in 8 different size groups (sizes 44-58) according to the recommended size ranges in EN 13402-3:2017 (Size designation of clothes – Part 3: Size labelling based on body measurements and intervals). For the whole size range a proportional interval 4 cm was chosen between two adjoining body measurements. For each chest girth range, the average of the other sizes were calculated. The standard size was set on size 52, and all the width- and girth-measurements (except chest girth) and shoulder length of all sizes above and below size 52 were graded proportionally in order to have a proper and workable grading table. The other length measurements are based on an average height of 183,7 cm and are equal for the whole size range.

The body size chart of HWMR is shown in Table 16 and it is based on a dataset of 52 subjects of average age of 21.2±4, weight of 80.1±9.7 and stature of 183.7 ±7.1.

Table 16 Body size charts of HWBR for garments size 44-58

Size (range chest girth)								
(ISO 8559-1:2016)	**44 (86-90)**	**46 (90-94)**	**48 (94-98)**	**50 (98-102)**	**52 (102-106)**	**54 (106-110)**	**56 (110-114)**	**58 (114-118)**
N	1,0	1,0	8,0	9,0	17,0	9,0	4,0	3,0
Average age	22,0	18,0	21,0	21,1	20,1	22,0	21,8	25,0
Weight	54,0	62,9	71,0	77,0	81,6	85,3	90,6	90,7
Height	163,7	175,0	179,6	181,7	186,1	186,2	187,1	184,9
Chest girth	**88,0**	**92,0**	**96,0**	**100,0**	**104,0**	**108,0**	**112,0**	**116,0**
Waist girth	**74,0**	**76,5**	**79,0**	**81,5**	**84,0**	**86,5**	**89,0**	**91,5**
Top hip girth	**74,0**	**77,0**	**80,0**	**83,0**	**86,0**	**89,0**	**92,0**	**95,0**
Hip girth	**90,5**	**93,0**	**95,5**	**98,0**	**100,5**	**102,0**	**104,5**	**107,0**
Waist height	115,0	115,0	115,0	115,0	115,0	115,0	115,0	115,0
Across back width	**40,5**	**41,0**	**41,5**	**42,0**	**42,5**	**43,0**	**43,5**	**44,0**
Across front width	**35,0**	**36,5**	**38,0**	**39,5**	**41,0**	**42,5**	**44,0**	**45,5**

Back neck point to waist	**45,5**	**45,5**	**45,5**	**45,5**	**45,5**	**45,5**	**45,5**	**45,5**
Neck girth	**35,0**	**36,0**	**37,0**	**38,0**	**39,0**	**40,0**	**41,0**	**42,0**
Neck base girth	**38,0**	**39,0**	**40,0**	**41,0**	**42,0**	**43,0**	**44,0**	**45,0**
Shoulder length	**15,5**	**15,7**	**15,9**	**16,1**	**16,3**	**16,5**	**16,7**	**16,9**
Shoulder slope	5,9	5,9	5,9	5,9	5,9	5,9	5,9	5,9
Arm length	62,5	62,5	62,5	62,5	62,5	62,5	62,5	62,5
Upper-ar m girth	**28,5**	**29,5**	**30,5**	**31,5**	**32,5**	**33,5**	**34,5**	**35,5**
Wrist girth	**16,2**	**16,4**	**16,6**	**16,8**	**17,0**	**17,2**	**17,4**	**17,6**
Inside leg length	85,0	85,0	85,0	85,0	85,0	85,0	85,0	85,0
Thigh girth	**52,0**	**54,5**	**56,0**	**57,5**	**59,0**	**60,5**	**62,0**	**63,5**
Knee girth	**36,0**	**37,0**	**38,0**	**39,0**	**40,0**	**41,0**	**42,0**	**43,0**
Calf girth	**34,5**	**35,5**	**36,5**	**37,5**	**38,5**	**39,5**	**40,5**	**41,5**
Ankle girth	**24,0**	**24,5**	**25,0**	**25,5**	**26,0**	**26,5**	**27,0**	**27,5**
Knee height	52,0	52,0	52,0	52,0	52,0	52,0	52,0	52,0

Significant differences were found between the body measurements of average Belgian male and HWMR (*Deliverable 2.5*), therefore a lack of fit is expected for the garment of HWMR developed based on measurements of average Belgian man (BM). The size charts presented in this deliverable will be validated by comparing garment fit against a prototype based on generic size charts of BM (*Deliverable 5.2*)

5.5 COMPARISON OF SELECTED BODY MEASUREMENTS OF ROWERS EXTRACTED FROM 2D (QUANTACORP PHOTOMETRY) AND 3D SCANS (3D BODY SCANNING)

Body measurements acquired by 3D body scanning and 2D photogrammetry were compared aiming at assessment of QuantaCorp suitability for the purpose of garment patterning. A total of *23 body measurements of 55 rowers,* median age 20 years, extracted from 3D body scans (A-pose) and from 2D pictures.

Significant large differences (cm) were noticed between 3D-2D technology for 13 out 23 body measurements. In most of the cases the measurements extracted from 3D scans where larger than 2D, more details in Deliverable 2.6

The 3D-2D difference for many primary body measurements used in garment patterning indicates more research is needed to investigate how 2D technology can be best used to replace or augment 3D technology for the purpose of (tight) garment patterning.

5.6 CASE STUDIES

DECCA: MATERIALS

Materials: n=2 fabrics, PES/ PP (outside/inside) untreated and treated (printed), 230 g/ m^2

Aim: Influence of sublimation printing on: waterproofness, air permeability, water vapor permeability, moisture management MMT, see description of methods in *D4.2 Comfort tests*.

Results: comprehensive confidential report including test methods and results.

LIEBAERT: MATERIALS

Materials: ten knitted PA/elastane fabrics, 135-270 g/ m^2

Aim: Characterize and compare the fabrics according to several comfort-related properties such as: moisture management, water vapour permeability, air permeability, moisture drying time (alkaline and acid sweat), thermal properties and compression. Moreover the variation of air permeability and pressure (10/30% stretch) with domestic washing (5 / 10/ 15 cycles) was assessed as well as the variation of air permeability with bidirectional stretch (5%, 10%). Description of test methods is available in deliverable D*4.2 Comfort tests.*

Results: comprehensive confidential report including test methods and results.

BIORACER: MATERIALS

Materials: n=2; 64/36 PA/EL (TI 130 PES), 167 g/m^2 and 75/25 (PES/EL), 136 g/m^2 (ARCH-T Graphene)

Aim: assessment of comfort properties (i.e. moisture management, air permeability, moisture drying time and thermal conductivity), compression and seam slippage and 2) influence of domestic washing (10, 20 cycles) and stretch (10% and 20%) on fabric comfort properties and compression. Description of test methods is available in deliverable D*4.2 Comfort tests.*

Results: comprehensive confidential report with the test methods and results.

DECATHLON: MATERIALS

Materials: 51 fabrics for sportswear.

Aim: assessment of hand of the fabrics according to Fabric Touch tester (FTT), assessed on two sides and two fabric directions.

Results: comprehensive confidential report including test methods and results.

DECCA: HANBIKERS SUIT

Aim: development of a handbiker sport suit to meet individual needs of two test persons, who have problems related to fit (upper/lower body), body temperature, sweat, clothes donning and functionality.

Materials: two fabrics with different moisture management capabilities were used at different body locations according to 3D body maps for sweat.

	mposition	per unit area ;/ m^2)	)MMC	ıg time nin)	ermeability (mm/s)
l Full Moon	;/EL 86/14	105	3±0,018	±0,79	991±32
2 Asteria s and body)	;/EL 86/14	130	46±0,02	±0,61	473±63

Test subjects:

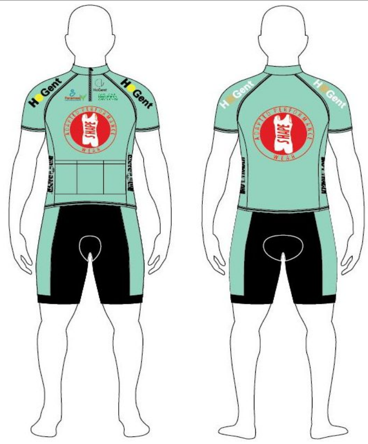
rson 1	rson 2
HDG	MO
, weight 85 kg, 1m86, BMI 24.56	, weight 103 kg, 1m90, BMI 28.53
d since 2010 (motorbike accident), MH3 disability	d since 2016 (work accident), MH3 disability
g (hours/week): 6-8 , 14 h (2017)	g (hours/week): 6-8
on back	on upper torso

Problems and requirements of the test subjects:

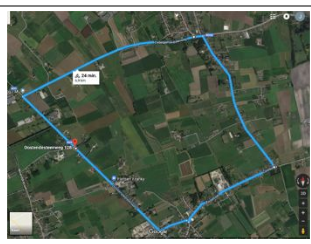
- sweat, comfort & functionality.
- fit (*tailor-made needed)*, comfort, no elastics on sleeves & bottom side, no pockets on back> # 3 in front; short zip

Final garment design

- ✓ short zip, 3 pockets in front
- ✓ manual body measurement & adapted patterns (i.e. Bioracer)
- ✓ fit control & adjusting
- ✓ digital printing of each garment part
- ✓ position & size logo's sponsors & manufacturer ~ requirements UCI (Union Cycliste Internationale): logo Shape=manufacturer



Test protocol

Weather conditions (Ichtegem, 8/05/2018, 11-13 u): 48-54 % RH; Outside temperature 22.5-24.1° C; wind speed 5 km/h	
Cycling: ~6,9 km route; cycling speed: 23-24 km/h; duration: 15' (CON); 20' (DECCA)	
Sportswear: CON (Control= own sport suit) and DECCA (materials)	
Qualitative analysis, each 5' assessment of: ✓ sweat sensation scale, 4-point scale: 0 (neutral)...3 (very wet) ✓ torso temperature sensation, 9-point scale: -4 (very cold) ...+4 (hot) ✓ thermal comfort sensation, 4-point scale: -3 very uncomfortable...0 comfortable	
Quantitative analysis ✓ Sweat loss (SL): weight of T-Shirts before/after training ✓ Hart rate ✓ Torso skin temperature (IR camera): front only	

Results:

✓	Test person 1 & 2: overall comfort, fit and design: OK
✓	Sweat & temperature sensations: both outfits OK (Decca outfit recommended for summer; Bioracer for colder weather, see materials in 2.6)
--	*ecks in field-vivo test*: uncontrolled weather conditions; constant cycling intensity difficult to guarantee; torso sweat mapping by absorption pads difficult to assess in field (privacy); SL assessment by weight loss of test person: not possible in field.
	l improvement needed: - continuous skin temperature monitoring (sensors) as alternative to overcome disadvantages of IR camera (due to lying position, back skin temperature not possible to assess)

	- longer cycling trail or/and higher intensity: behavior by higher sweat loss SL - in-vivo test in lab, controlled environment - long-term evaluation materials/design/quality/comfort

Reporting: results presented in Bachelor thesis Kirsten De Klerck (June 2018) and UC meeting (15/5/2018)

BIORACER: HANDBIKER SUIT

Materials

	mposition	per unit area g/ m^2)	OMMC	ing time (min)	r permeability (mm/s)
l Cold Black (back)	A/PES/EL 2/21/17	245	0,36±0,02	5±1,48	745±94
2 Anibal s and body)	PES/EL 81/19	155	0,20±0,02	5±0,04	174±11

- Test subjects: see 2.5 DECCCA
- Design: See 2.5 DECCCA
- Results: see 2.4 DECCA

Reporting: presentation Kirsten Declerk (results presented in June 2018, bachelor thesis defence) and UC meeting (15/5/2018).

BIORACER: MALE ROWERS UNISUIT

Aim: development of a rower unisuit for heavy-weight, male rowers (HWMR) and validation of the size charts (Deliverable 5.1) against size charts for average Belgian population (developed in SMARTFIT project, HOGENT, 2013-2014).

Materials: three fabrics with different moisture management capabilities were used at different body locations according to 3D body maps for sweat.

	Composition	per unit area (g/m^2)	MMC	ing time min)+	ermeability
l Anibal 2.0 *(upper body, fronts side+ trousers under)*	19 EL/81 PES	156± 2	±0.04	14±0.39	258±3

2 Coldblack light *(upper body back side+ side panels)*	PA/13 PES/11 EL	156±5	±0.02	64±0.32	139±45
3 Espadon 150 *ide trousers+ buttocks panel)*	71 PA/29 EL	147 ± 4	0	n.a.[++]	105±11

[+] alkaline sweat; [++]test method ISO 17617-2014 not suitable for this fabric

Test subject: Heavy weight male rower (HWMR), age 23, garment size 58.

Test protocol

Test conditions:
Sport wear: CONTROL (SMARTFIT size charts) versus SHAPE (size charts HWMR) versus *BIORACER (3XL)*

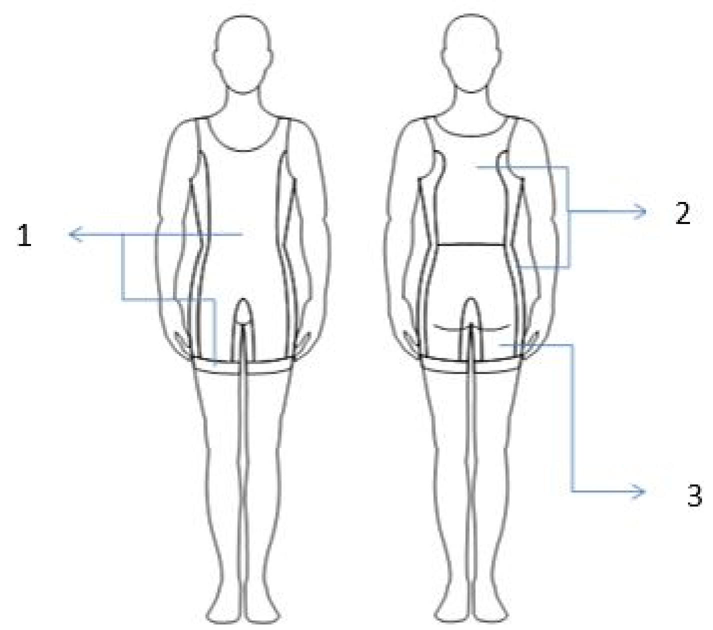
Qualitative analysis

- ✓ Fit: 5-point scale: 1= extremely poor fit; 2= poor fit; 3= average fit; 4= good fit; 5= excellent

Fit: overall, chest circumference, back width, back length, arm hole, tight circumference, leg length

- ✓ Local pressure comfort at level of thigh and chest: 5-point scale: 1=very tight; 2=tight; 3=comfortable tight; 4= loose; 5= very loose ??

Design: combined requirements of rowers (Deliverable 1.2) and design BIORACER



Nr.	Fabric
1	Anibal 2.0
2	Coldblack light
3	Espadon

Results: partial results in D5.2 and final meeting 10/12/2018. Final results in Bachelor thesis Celien De Bishop, to be presented in June 2019.

LIEBAERT: GLOVES

Materials: 3 knitted PA/elastane fabrics, 135-270 g/ m^2

Aim: Evaluate usefulness of the material in creating a compressive glove. Elastic properties have been determined using a tensile tester. Based on this a glove pattern was made aiming at 10 mmHg based on D3.1 and D3.2.

Results: Pressure values in the glove were tested with Pico-press. Values found showed great variation as curvature varies greatly from palm (1 mmHg) of hand to e.g. side (14 mmHg), but overall pressure is around 10.4 mmHg. This shows the need of virtual modelling to evaluate positional pressure and dynamic pressure. More details in D5.2.

ELASTA: THUMB GUARD

Materials: woven, knitted and braided bands. Braided CO50/2x2, 13 coils was selected for the guard.

Aim: Use the band to limit movement of the thumb on contact as a protection against sprains (ulnar collateral ligament injuries).

Results: Based on D3.2 a prototype for a thumb guard was developed based on the Liebaert gloves and Elasta bands. A combination of elastic band/textile and non-elastic band is required to obtain the required functionality. More details in D5.2.

6. Conclusions

The overall objective of SHAPE project Adapted Performance Sportswear was to develop comfortable, fitted and functional (sports)wear for elite athletes. The results of this project will make a major contribution to the development of this type of sportswear.

1. It was found that the anthropometrics of elite cyclists and rowers differs significantly from the average.
2. To ensure a perfect fit, casual and sportswear for elite rowers should be made starting from customized size charts which were developed in the framework of this project.
3. Most of anthropometric changes due to sport specific postures were statistically significant. In general, it seems that posture led to more influence on pressure than on anthropometrics. Nevertheless, the absolute values of maximum 10 mmHg indicate a low pressure and thus adequate garment pressure comfort. Therefore it is argued that in case of elastic sportswear fabric elasticity will accommodate the body changes induced by the posture and no further allowance should be added to the garment pattern. However, this assumption should be validated by prototypes, especially in case of casual garment and low-elasticity fabrics.
4. A set of test methods was developed to allow testing of comfort and functional properties of elastic garments. This was successfully applied to materials obtained from the partners.

5. Virtual prototyping was used to investigate the effect of the elastic garments on the body. Pressure values in compression garments e.g. compressive glove showed great variation where curvature of the body varies greatly. This confirms the need of virtual modelling to evaluate positional pressure and dynamic pressure.
6. The research results were applied in 9 test cases going from improvements to materials to dedicated handbiker suits. These test cases showcase how the SHAPE project results can help in improving fitted, functional sportswear.
7. Body measurements acquired by 3D body scanning and 2D photogrammetry were compared aiming at assessment of QuantaCorp suitability for the purpose of garment patterning. Significant large differences (cm) were noticed.

Future work and recommendations:

1. The 3D-2D difference for many primary body measurements used in garment patterning indicates more research is needed to investigate how 2D technology can be best used to replace or augment 3D technology for the purpose of (tight) garment patterning.
2. Further validation of the customized size charts.
3. Investigation of whether extra allowances to accommodate body changes induced by posture should be added to the garment patterns in case of low-elasticity fabrics, casual wear and particularly workwear.
4. Further validation of 3D body mapped clothing.