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Fit evaluation of sportswear for Belgian elite male rowers in static and dynamic rowing postures

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Abstract. The main objective of the SHAPE study was to assess the anthropometry of elite male rowers and develop customized size charts and sportswear with adequate fit in static and dynamic rowing postures. This paper briefly discusses the anthropometry of Belgian elite male rowers and focuses on the fit features of a related unisuit called SHAPE which is compared against a reference (SMARTFIT) with similar materials and design, whereof the garment construction is based on body charts of average Belgian males. Four elite male rowers evaluated both unisuits in garment size 52 and 58. Most of the ten fit features investigated for SHAPE unisuit were allocated average scores between 3 (adequate fit) and 4 (very good fit). In static posture, the overall fit of the SHAPE unisuit was found slightly better than of SMARTFIT unisuit (average score 3.8 and 3.1 respectively). Unlike SMARTFIT, SHAPE unisuit based on rowers body dimensions scored equally well in static and dynamic rowing postures catch and finish and will likely successfully accommodate repetitive sport movements.

1. Introduction

To ensure great freedom of movement, perfect fit and comfort, regardless of any sport-specific movement, sportwear shall consider body proportions and shape of elite athletes who categorically differ from the average population. Several international studies [1-7] reported deviation of rowers anthropometry from average population but they did not link anthropometry to garment patterning and fit of the sportswear in sport- specific posture was rarely investigated.

The main objective of the SHAPE study [8] was to develop sportswear with adequate fit in both static and dynamic rowing postures. Therefore the anthropometry of Belgian elite male rowers (age 18-35 years) was first assessed using a 3D body scanning technique and eventually customized size charts were developed. Significant differences were found between the body measurements of heavy weight male rowers and average Belgian males of same age [8]. This study quantified moreover the influence of the catch and finish rowing postures on selected body measurements and investigated the fit of the corresponding sportswear [9]. This paper briefly discusses the anthropometry of Belgian elite male rowers assessed by 3D body scanning and zooms in on fit features of related SHAPE unisuit which were evaluated in static and dynamic rowing postures. Fit of SHAPE unisuit was also compared against a

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reference unisuit (SMARTFIT) whereof the construction is based on average body measurements of Belgian males [10].

2. Materials and methods

2.1. Rowers anthropometry assessment and body size charts development

The target group was scanned using 3D body scanners with structured light (i.e., Symcad and TC^2). A number of n=20 body measurements were extracted [11] for a total number of n=54 elite male rowers (of which 32 were Belgian), age 18-35 (mean age 21.0 ± 4.0 years). A number of 41 subjects belonged to the heavy weight category (>72.5 kg) and 13 subjects to the lightweight category (< 72.5 kg). The rowers had the following demographics (Mean± SD): height 183.6±6.8 cm, body mass 80.5±9.2 kg and Body Mass Index (BMI) 23.8±1.9 kg/m^2. Thirteen significant differences ($p<0.05$) in the body measurements were identified, especially the chest girth and stature (i.e., heavy weight rowers > 4 cm larger than average Belgian male of same age). Length of chest, back and legs was also significantly larger (up to max 4 cm) for the heavy weight rowers.

A dataset of n=52 rowers was used to develop body sizing charts. According to ISO 8559-2:2017 [12] chest girth was defined as the primary dimension. The subjects were categorized in 8 different size groups (sizes 44-58) according to the recommended size ranges [13]. For the whole size range a proportional interval of 4 cm between two adjoining body measurements was chosen. For each chest girth range, the average of the other sizes was calculated. The standard size was set on size 52 and except chest, all girths and shoulder length were graded proportionally. Other length measurements are based on an average height of 183,7 cm and are equal for the whole size range. Table 1 shows comparatively the average body measurement of Belgian males SMARTFIT [10] and elite rowers SHAPE [8] based on a dataset of 307 Belgian males and 52 rowers respectively.

Table1. Sizing charts size 52 and 58 according to average Belgian males (SMARTFIT) and elite rowers (SHAPE) showing the body differences between the two groups.

	Size 52			Size 58		
Body measurements (cm)	SMARTFIT	SHAPE	Difference SHAPE-SMARTFIT	SMARTFIT	SHAPE	Difference SHAPE-SMARTFIT
Body height	180	186.1	+ 6.1	180	184.9	+ 4.9
Chest girth	104.0	104.0	0.0	116.0	116.0	0.0
Waist girth	88.0	84.0	- 4.0	100.0	91.5	- 8.5
Top hip girth	92.5	86.0	- 6.5	105.0	95.0	- 10.0
Hip girth	101.5	100.5	- 1.5	110.5	107.0	- 3.5
Waist height	111.7	115.0	+ 3.3	111.7	115.0	+ 3.3
Across back width	40.0	42.5	+ 2.5	41.8	44.0	+ 2.2
Across front width	40.5	41.0	+ 0.5	43.5	45.5	+ 2.0
Back neck point to waist	43.0	45.5	+ 2.5	43.0	45.5	+ 2.5
Neck girth	40.0	39.0	- 1.0	43.0	42.0	- 1.0
Neck base girth	45.5	42.0	- 3.5	48.5	45.0	- 3.5
Shoulder length	15.8	16.3	+ 0.5	16.7	16.9	+ 0.2
Shoulder slope	6.0	5.9	- 0.1	6.0	5.9	- 0.1
Arm length	60.1	62.5	+ 2.4	60.1	62.5	+ 2.4
Upper-arm girth	33.0	32.5	- 0.5	36.0	35.5	- 0.5
Wrist girth	17.6	17.0	- 0.6	18.8	17.6	- 1.2

Inside leg length	81.9	85.0	+ 3.1	81.9	85.0	+ 3.1
Thigh girth	59.0	59.0	0.0	63.5	63.5	0.0
Knee girth	39.5	40.0	+ 0.5	42.0	43.0	+ 1.0
Calf girth	39.0	38.5	- 0.5	42.0	41.5	- 0.5
Ankle girth	25.5	26.0	+ 0.5	27.0	27.5	+ 0.5
Knee height	49.9	52.0	+ 2.5	49.9	52.0	+ 2.1

2.2. Materials and prototypes development

Three types of fabric for sportswear exhibiting various composition, elasticity and moisture management properties were selected for the development of the prototypes. To envisage elevated comfort level, fabric 2 with enhanced moisture management, air permeability and short drying time (Table 2) was placed on the back side, which is potentially prone to a large amount of sweat during rowing. Fabric 1 was used in the front panel and fabric 3 on the buttock respectively (Figure 1a).

Table 2. Physical and comfort properties of the fabrics 1-3 used for the rowing unisuit.

		Fabric 1 knitted	Fabric 2 knitted	Fabric 3 woven
Composition (%)		81 PES/ 19 EA	76 PA/13 PES/ 11 EA	71 PA/ 29 EA
Mass (g/m^2) [14]		156±2	156±5	147±4
Thickness (mm) [15]		0.5±0.00	0.6±0.01	0.42±0.00
Elongation (%) [16]	Wales/warp	155±2	128 ±4	89±1
	Courses/weft	223±3	99±2	95±1
Drying time (min) [17]		46±0.4	28±0.3	-
OMMC [18]		0.4±0.03	0.55±0.01	0
Air permeability (mm/s) [19]		258.5±3	1394±45	105±11

Two unisuits called SHAPE were developed in garment size 52 and 58 (Table 1). Design was decided considering the preferences of the rowers and aiming at improving shortcomings of existing rowing suits. [20] Equally two unisuits called SMARTFIT with similar design and materials (Figure 1a) were produced starting from average body measurements of Belgian males.

(a) (b)

Figure 1. Front (left) and back view (right) of the unisuit indicating the fabrics 1-3 used (a) and virtual fit of SHAPE unisuit size 52 in front, back and lateral view (b) [20].

2.3 Garment fit assessment in rowing postures

During a rowing stroke, four positions can be distinguished, among which flexed posture “catch” and extended posture “finish” potentially lead to significant body changes, both in lengths and girths. During the catch (figure 2a) the legs are compressed, the shins are vertical, arms are extended, triceps work to extend the arms, and the flexor muscles of the fingers and thumbs grip the handle. The back muscles are relaxed, and abdominals are flexing the torso forward. [21]At the finish (Figure 2c), the abdominals stabilize the body, and the glutes and quads are contracting. The biceps and many of the back muscles are also contracting to help keep the torso in the finish position and to internally rotate the upper-arms. [21] Changes of both upper and lower body upon posture are relevant for the purpose of garment development in general and they likely change most upon catch and finish posture.

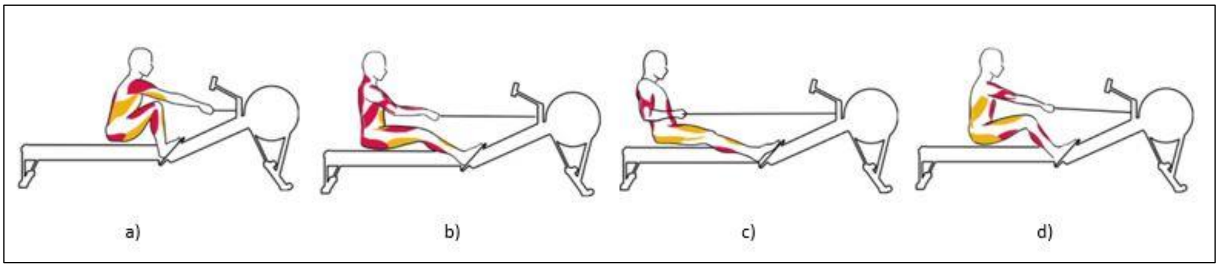

Figure 2. Rowing stroke and muscles involved in a) catch, b) drive, c) finish, d) recovery (permission from Concept2, Inc.).

Four elite male rowers having previous experience with fit assessment, evaluated the fit of the two outfits standing as well as in catch and finish rowing postures on an ergometer. The overall fit and ten other fit features of outfit SHAPE and reference unisuit SMARTFIT were assessed on a 5-point scale (1= extremely poor fit, 5= excellent fit).

3. Results and discussions

Most of the average scores assigned to the fit features of SHAPE unisuit (figure 3) were between 3 (adequate fit) and 4 (very good fit). Fit was found adequate at level of chest girth CG and thigh girth TG regardless the posture. Similarly neck line NL, pants length LL and arm cut AC_B (of back panel) were equally good (average score 4 in static and dynamic postures). A decrease of the average fit on waist WG and hip HG was noticed upon dynamic postures as well as a slight decrease of fit for back length BL and arm cut front AC_F. Three test persons were slightly smaller than the size of the suit they evaluated, which likely explains the large variability (standard deviation) of the scores assigned to most of the fit features.

The overall fit of the SHAPE unisuit (figure 4) in static posture was found slightly better than of SMARTFIT unisuit (average score 3.8 and 3.1 respectively). Moreover SHAPE protype scored equally well both in static and dynamic postures. On the contrary SMARTFIT unisuit based on body size charts of average Belgian males had a poorer fit (average score 2.8) in catch and finish posture and will likely impede repetitive rowing movements. SHAPE unisuit was found statistically significant better (t-test, $p<0.05$) than SMARTFIT, in static and dynamic postures by three of four test persons with respect of all fit features considered. Figure 1b displays the virtual fit of unisuit SHAPE on an avatar with body dimensions of a rower size 52.

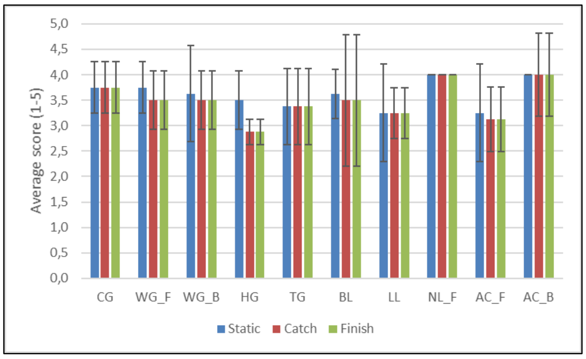

Figure 3. Average fit features of SHAPE outfit in static and two dynamic rowing postures.

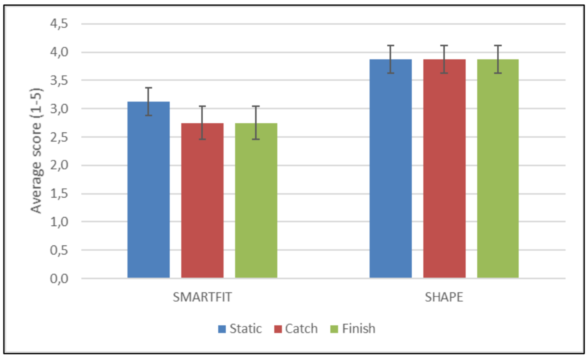

Figure 4. Overall fit evaluation of SMARTFIT and SHAPE outfits in static and dynamic posture.

4. Conclusions

The overall fit of unisuits SHAPE was positively evaluated by the rowers regardless of the posture which suggests that the body size charts were correct, despite a rather limited number of subjects considered (n=52 rowers). Fabrics 1 and 2 used for the garment's body had an elongation between 99-223 % depending on testing direction, which seems to be sufficient to accommodate body changes due to dynamic postures. Nevertheless, in case of fabrics with lower elasticity, extra ease may be necessary to ensure adequate fit regardless of the posture. These aspects along with the feedback of the test persons will be considered in development of future prototypes. Special attention will be payed to selection of test persons whose body sizes perfectly match the size of the garment tested.

Finally, unisuit SHAPE developed based on anthropometry of elite male rowers exhibited better fit than outfit SMARTFIT based starting from average body measurements of Belgian males, especially in dynamic rowing postures.

Acknowledgments

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References

[1] Bourgois J, Claessens A L, Vrijens J, Philippaerts R, Van Renterghem B, Thomis M, Janssens M, Loos R and Lefevre J 2000 Anthropometric characteristics of elite male junior rowers *British Journal of Sports Medicine* **34** pp 213-216

[2] Bourgois J, Claessens A L, Janssens M, Van Renterghem B, Loos R, Thomis M, Philippaerts R, Lefevre J and Vrijens J 2001 Anthropometric characteristics of elite female junior rowers *Journal of Sports Sciences* **19** pp 195-20

[3] Claessens A, Bourjois J, Van Aken K, Van der Auwera R, Philippaerts R, Thomis M, Vrijens J, Loos R and Lefevre J 2005 Body proportions of elite male junior rowers in relation to competition level, rowing style and boat type *Kinesiology* **37**(2), pp 123-132

[4] Forjasz J 2011 Anthropometric Typology of Male and Female Rowers Using K-Means Clustering *Journal of Human Kinetics* **28** pp 155-164

[5] Schranz N, Tomkinson G, Olds T and Daniell N 2010 Three-dimensional anthropometric analysis: Differences between elite Australian rowers and the general population *Journal of Sports Sciences*, **28,** pp 459-469

[6] Mikulic P 2008 Anthropometric and physiological profiles of rowers of varying ages and ranks *Kinesiology* **40** pp. 80-88

[7] Mikulic P, Ruzic L and Oreb G 2007 What distinguishes the Olympic level heavyweight rowers from other internationally successful rowers? *Collegium Antropologicum* **31** pp. 811-816

[8] Malengier B,Vasile S, De Raeve A, Cools J, Deruyck F,Teyeme Y and Langenhove L 2019 *Results of SHAPE project Adapted performance wear* IWT TETRA HBC.2016.0078
[9] Vasile S, Cools J, De Raeve A, Mallengier B and Deruyck F,2019, Effect of rowing posture on body measurements and skin-sportswear interface pressure and implications on garment fit, *Journal of Industrial Textiles p.*1528083719877005
[10] SMARTFIT Adapted performance wear [project IWT 110139]
[11] ISO 8559-1:2017 *Size designation of clothes - Part 1: Anthropometric definitions for body measurement*
[12] ISO 8559-2:2017 *Size designation of clothes - Part 2: Primary and secondary dimension indicators*
[13] EN 13402-3:2017 *Size designation of clothes – Part 3: Size labelling based on body measurements and interval*
[14] ISO 3801:1977 *Textiles – Woven fabrics – Determination of mass per unit length and mass per unit area*
[15] ISO 5084:1996 *Textiles – Determination of thickness of textiles and textile products*
[16] EN 14704-1:2005 *Determination of the elasticity of fabrics - part 1: Strip tests*
[17] ISO 17617:2014 *Textiles – Determination of moisture drying rate*
[18] AATCC 195:2011 *Liquid Moisture Management Properties of Textile Fabrics*
[19] ISO 9237:1995 *Textiles – Determination of the permeability of fabrics to air*
[20] De Bisschop C 2019 *A study on the optimisation of garment fit and comfort of roing suits for male Belgian rowers,* bachelor thesis, University College Gent
[21] https://www.concept2.com/indoor-rowers/training/muscles-used Accessed on 10 April 2019