3D Body Databases of the Spanish Population and its Application to the Apparel Industry

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Abstract

Since the year 2000, many anthropometric surveys have been conducted across the world using 3D body scanning technologies, most of them addressed to the apparel industry. This paper describes the application to the apparel industry of the 3D Spanish surveys (female, male and children) conducted from 2007 to 2015 by IBV gathering over 12.000 individual scans. It also presents tools that will help the apparel manufacturers and retailers to make an effective use of Spanish databases in the design as well as in the labelling of products addressed to the Spanish market and following the forthcoming size designation interval standards (EN 13402). These tools consist of a website providing with the basic anthropometric statistics, two books with the population measurements by age range (one for female and one for male populations), a collection of digital mannequins and a collection of physical mini-mannequins (scale 1/20). Moreover, the access to the 3D databases makes possible to IBV to extend the use of these data for the provision of new consultancy services for clothing companies about how to improve garment design and fitting.

Keywords: 3D, anthropometry, body, male, female, children, size table, measurement, database, avatar, mannequin, scanning, shape, data-driven, PCA, statistical, garment, clothing, apparel, EN 13402 labelling, intervals

1. Introduction

Since the conduction of the CAESAR survey in the year 1999 [1], more than 20 large-scale national or specific population surveys have been conducted across the world [2] using 3D body scanning technologies of different kind [3,4,5]. The survey SizeUK (1999-2002) scanned 11,000 women and men using a full body 3D scanner from TC^2 and was co-funded by the UK government and British clothing retailers. Size UK was the first large-scale survey using a 3D body scanner specifically addressed to the apparel industry, and in particular, to contribute to the improvement the fit of garments. In the next years, similar projects were promoted and several surveys were conducted, the most relevant at USA, France, Germany, Thailand, Korea, India, Greece, Spain, Belgium, Sweden, Romania and Mexico (Table 1).

Table 1. Summary of the main 3D scanning surveys conducted across the world

Country	Project	Year	Sample size	Age range	Body scanner	Main target Industry
USA	CAESAR	2000	2,400	18 to 65	Cyberware	Ergonomics
Netherlands	CAESAR	2000	1,200	18 to 65	Vitus Pro	Ergonomics
Italy	CAESAR	2002	800	18 to 65	Vitus Pro	Ergonomics
UK	SizeUK [6]	2001-2002	10,000	16 to 76	TC^2	Apparel
USA	SizeUSA [7]	2002-2003	10,800	20 to 65	TC^2	Apparel
Germany	SizeGERMANY	2007-2009	12,000	6 to 65	Vitus Smart	Apparel, Automotive
France	France survey	2003-2004	11,500	5 to 70	Vitus Smart	Apparel
Spain	Spanish surveys	2007-2014	12,000	3 to 70	Vitus Smart	Apparel
India	SizeINDIA [8]	2009-2010	5,000	18 to 45	Vitus Smart	Apparel, Automotive
Thailand	SizeTHAILAND [9]	2007-2008	13,400	16 to 60	TC^2	Apparel
Korea	Korean survey [10]	2010	14,000	7 to 69	Hamamatsu	Apparel , Footwear
Belgium	SmartFit [11]	20013	5,500	3 to 75+	SYMCAD II	Apparel
Romania	Romanian Survey	2007-2009	1,300	20 to 65	Vitus Smart	Apparel

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The transfer of results to the apparel industry from these projects consisted on: digitally measuring the3D bodies following ISO 8559 [12] definitions, gathering them into databases and developing some physical and virtual mannequins representing the most popular garment sizes on each country. Although the economic investment required for large-scale 3D body surveys is very high, the exploitation and industry uptake of them has not been comparable. The level of adoption of these results by the apparel industry is still very low, being difficult to recoup the high cost of these studies. The lack of common guides for patternmaking, the voluntary character of sizing standards, the different language and definitions of body measurement, and the lack of common criteria and rules relating body measurements and garment measurements are the main barriers to the transfer the results of anthropometric surveys to the apparel industry.

In this sense, the main standardization committees have done a great effort to integrate the results of these anthropometric studies in the development on new standard for clothing. The results of SizeUSA were used as a reference to develop the ASTM standards of body dimensions for apparel design [13]. In Europe, the standard EN 13402-3:2013 defines sizing intervals for men, women, boys, girls and infants based on the national anthropometric studies of different European countries (i.e. Netherlands, France, Sweden, Germany, Romania and Spain). This standard proposes to substitute the size codes of garment (e.g. XS, S, M, L, XL, etc. or 36, 38, 40, 42, 44, etc.) by the use of the body measurements that would fit the person wearing that garment. The concept behind this standard is the use of body measurements for the size designation and labelling in order to communicate better to the customer the fitting characteristics of the garment.

In Spain, IBV conducted the Spanish female survey in 2007-2008 [14] and has recently completed the male and children surveys between 2013 and 2015 [15,16]. The whole Spanish 3D database comprises over 12.000 individuals in standing posture (Table 1) sharing a common homologous structure and includes over 50 measurements by individual. This paper presents a variety of tools to apply anthropometry knowledge of the population to improve garment design and fitting.

2. The Anthropometric data of the Spanish population

IBV conducted anthropometric surveys in order to characterize the Spanish population of adults and children for apparel industry (table 2). In the three studies the measurements were done with a 3D laser-based body scanner (Vitus Smart XXL) offering a level of accuracy of ±1 mm [3] in accordance with the international standard DIN EN ISO 20685.

Table 2. Summary of Spanish 3D surveys

Population	Age range	Year	Sample size	Posture
Spanish females	13 - 70	2007-2008	9,600	Standing(1)
Spanish females	13 - 70	2007-2008	2,400	Sitting(2)
Spanish male	13 – 65	2013-2014	1,400	Standing(1) & sitting(2)
Spanish children	3 - 12	2014-2015	1,000	Standing(3)

(1) Posture A and C defined in ISO 20685, (2) Posture D defined in ISO 20685; (3) Posture A defined in ISO 20685

The study of the female population finished on 2009 and measured 9,600 females from 12 to 70 years old including regular and big sizes [17]. The stratification of the sample covered ten groups of age enabling the analysis of specific market segments with sufficient statistical power. Two standing postures were captured for the whole sample used to get the set of measurements for apparel application. A random subset of 2,400 females was also scanned in sitting position in order to cover ergonomics demands of specialized garment. The measuring protocol was complemented with a demographic questionnaire including information about habits shopping clothing and problems to find good fitting cloth.

The anthropometric survey of the male population was conducted between 2014 and 2015 in cooperation with the Spanish clothing sector, in particular with the participation of FEDECON (national association) and ATEXGA (regional association). The sample was stratified in four age groups according to the market groups defined by the clothing industry associations. 1,400 males were scanned in standing and sitting postures and also answered a questionnaire about clothing shopping habits and fitting problems.

Between 2014 and 2015 IBV conducted the anthropometric survey of children. The study included children from 1 month to 12 years old. Babies (i.e. considered from 1 to 36 months) were measured with traditional methods according to the set of measurements defined in ISO 8559. Children (i.e. considered from 3 to 12 years old) were scanned with the Vitus XXL scanner in two standing postures.

3D scan data from all surveys was processed for the creation of posture-harmonised homologous models and for the extraction of body dimensions according to IBV methodology [18]. Body templates used for the female, male and children survey shared the same topology (50K vertices and 99K elements) and skeleton (17-bones) but had specific geometry to facilitate the template fitting process. 50 measurements where shared across the three surveys. This provided a database of individual body dimensions and a database of individual 3D homologous avatars with anatomical one-to-one vertex correspondence among them (figs. 1, 2 and 3).

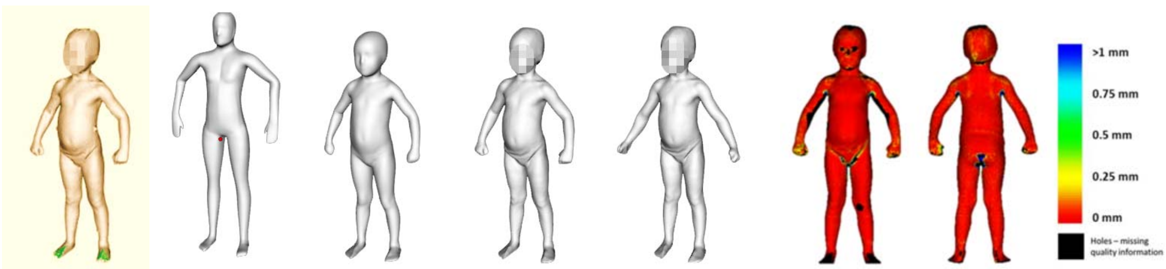

Fig 1. Illustration of the template fitting process and he quality map applied to children data

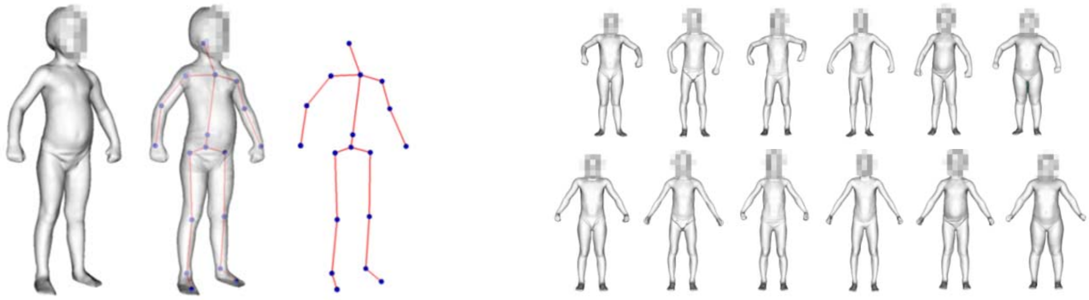

Fig 2. Skeleton-based posture harmonization of Spanish children's 3D database

3. Transfer of results to industry (adult data)

3.1 Sizing and labelling in the apparel industry

Nowadays each clothing company defines its own sizing chart, which is used to determine garment dimensions and labelling. The lack of regulations and the different labelling methods used on each country contribute to have a confusing buying process for consumers in terms of garment size selection. Depending on the brand (and even within the same brand), the customer's size may not be the same for products. With the market globalisation, the internationalisation of the companies and the growth of the online commerce, this problem is becoming increasingly important for apparel companies.

In this scenario, different standardization bodies (i.e. ASTM, ISO and CEN) have proposed alternative sizing and labelling methods based on body dimensions that can be easily taken by consumers either at home or at shops. In particular, the collection of European standards EN 13402 defines a bi-dimensional sizing method, i.e. based on a primary and a secondary measurement. The sizing concept of these standards is:

- For each type of garment, primary and secondary dimensions of the body are defined (EN 13402-2). The primary dimension is referred to the main body measurement used to create the size intervals (e.g. waist girth for male trousers). The secondary dimensions are critical body measurements for the garment fit (e.g. stature).
- The size code of the garment indicates the intervals of the primary and secondary measurements of the body that fit in.

Part 3 of the standard (EN 13402-3) includes a set of tables of sizing intervals combining primary and secondary dimensions for upper and lower garments for men, women, children and infants. The combination of intervals was obtained from the analysis of aggregated databases of different European countries (i.e. the Netherlands, France, Sweden, Germany, Romania and Spain).

Tools based on Spanish Adult data (books and mini-mannequins)

Following this approach, IBV conducted an analysis of the Spanish sizing surveys with the aim of defining the distribution of intervals combining pairs of primary and secondary dimensions for different type of garments. The results have been published on two books (females and males). Data is segmented in the following age ranges: young (14-34 y.o.); middle age (35-54 y.o.); senior (55-65 y.o.); and general population (16-65 y.o.). These books are addressed to clothing designers and patternmakers. These books include:

1. Description of the 37 body measurements considered according to EN 13402-1 (fig. 3)
2. Sizing tables that combine intervals of a pair of primary and secondary dimension. The tables report the mean anthropometric values of each subgroup of population (fig. 4).
3. Frequency distribution graphs that show the most frequent combination of primary and secondary intervals enabling the estimation of market shares for the Spanish market (figs. 5 and 6).

The visualization of human shapes of the body prototype representing the combination of intervals, a set of 3D printed figurines is also available in 1/20 scale (figs. 7 and 8).

Fig. 3. Example of graphical description of measurements

CONTORNO PECHO	Referencia	76					80					84				
	Intervalo	74-78					78-82					82-86				
CONTORNO CINTURA	Intervalo	59-63	61-65	63-67*	65-69	67-71	63-67	65-69	67-71*	69-73	71-75	67-71	69-73	71-75*	73-77	75-79
1	Estatura	162,1	161,5	160,8	160,2	159,5	162,3	161,7	161,0	160,3	159,7	162,5	161,8	161,2	160,5	159,9
2	Altura séptima cervical	138,2	137,6	137,1	136,6	136,1	138,4	137,9	137,4	136,8	136,3	138,6	138,1	137,6	137,1	136,5
3	Altura delantera de cuello	132,1	131,5	130,9	130,3	129,7	132,3	131,7	131,2	130,6	130,0	132,6	132,0	131,4	130,8	130,2
4	Contorno cuello	30,4	30,8	31,1	31,2	31,6	31,3	31,6	32,0	32,4	32,8	32,2	32,6	33,0	33,3	33,7
5	Contorno brazo superior	24,8	25,1	25,1	25,5	25,8	25,7	26,1	26,1	26,5	26,8	26,7	26,9	27,1	27,4	27,5
6	Contorno muñeca	13,8	13,8	13,9	14,0	14,1	14,1	14,2	14,3	14,3	14,4	14,4	14,5	14,6	14,7	14,8
7	Distancia cuello-cadera	56,4	56,1	55,9	55,5	55,4	56,4	56,2	55,9	55,7	55,6	56,4	56,2	55,9	55,7	55,6
8	Longitud brazo	53,8	53,7	53,6	53,5	53,3	54,0	53,9	53,8	53,6	53,5	54,2	54,1	54,0	53,8	53,7
9	Longitud brazo superior	30,0	30,0	30,0	29,9	29,9	30,1	30,1	30,0	30,0	30,0	30,2	30,1	30,1	30,1	30,0
10	Longitud antebrazo	23,8	23,7	23,6	23,5	23,4	23,9	23,8	23,7	23,6	23,6	24,0	23,9	23,9	23,8	23,7
11	Longitud cuello-cintura sobre el pecho	42,0	42,0	42,0	42,0	42,0	42,6	42,6	42,6	42,5	42,5	43,2	43,2	43,1	43,1	43,1
12	Caída de pecho	24,7	24,8	25,0	25,1	25,3	25,7	25,8	26,0	26,1	26,3	26,8	26,9	27,0	27,2	27,3
13	Contorno bajo-pecho	65,0	65,5	66,4	66,9	67,4	67,8	68,7	69,4	70,0	70,9	71,2	71,9	72,5	73,5	74,2
14	Contorno pecho	76,0	76,0	76,0	76,0	76,0	80,0	80,0	80,0	80,0	80,0	84,0	84,0	84,0	84,0	84,0
15	Separación pecho	15,8	15,9	15,9	16,0	16,0	16,6	16,6	16,6	16,7	16,7	17,3	17,3	17,3	17,4	17,4
16	Longitud axila-cintura	24,9	24,7	24,6	24,4	24,2	24,6	24,4	24,2	24,1	23,9	24,3	24,1	23,9	23,8	23,6
17	Anchura espalda	31,5	31,6	31,7	31,7	31,8	32,3	32,4	32,5	32,6	32,6	33,1	33,2	33,3	33,4	33,5
18	Longitud cuello-axilas	12,1	12,1	12,0	12,0	12,0	12,4	12,4	12,4	12,4	12,3	12,8	12,7	12,7	12,7	12,7
19	Longitud trasera cuello-cintura	38,7	38,7	39,4	39,3	39,3	38,8	39,5	39,4	39,4	39,3	38,8	39,5	39,5	39,4	39,5
20	Longitud hombro	13,3	13,2	13,1	13,0	12,9	13,4	13,3	13,2	13,1	13,0	13,5	13,4	13,3	13,2	13,1
21	Anchura hombros	34,6	34,5	34,5	34,5	34,4	35,3	35,3	35,2	35,2	35,1	36,0	36,0	35,9	35,9	35,9
22	Contorno cintura	61,0	63,0	65,0	67,0	69,0	65,0	67,0	69,0	71,0	73,0	69,0	71,0	73,0	75,0	77,0
24	Contorno caderas	88,6	89,2	89,8	90,5	91,1	90,9	91,5	92,1	92,7	93,5	93,2	93,8	94,5	95,2	96,0
25	Contorno cadera inferior	91,1	91,6	91,8	92,4	92,7	93,0	93,4	93,8	94,3	94,7	95,0	95,4	95,9	96,3	97,0
26	Tiro delantero	25,3	25,3	25,3	25,3	25,3	25,6	25,6	25,7	25,7	25,7	26,0	26,0	26,1	26,1	26,1
27	Tiro trasero	28,8	28,9	29,0	29,0	29,1	29,6	29,6	29,7	29,8	29,8	30,3	30,3	30,4	30,5	30,6
28	Longitud cintura-nalgas	19,5	19,1	18,8	18,7	18,3	19,3	19,0	18,7	18,4	18,2	19,2	18,9	18,6	18,2	18,1
29	Longitud trasera cintura-nalgas	18,8	18,5	18,2	18,1	17,8	18,7	18,4	18,1	17,8	17,7	18,6	18,3	18,0	17,8	17,6
31	Contorno muslo	52,9	53,1	53,3	53,5	53,7	54,2	54,4	54,6	54,8	55,0	55,4	55,7	55,9	56,1	56,3
32	Contorno rodilla	33,2	33,4	33,7	33,9	34,2	34,0	34,2	34,5	34,7	34,9	34,8	35,0	35,3	35,5	35,7
33	Contorno tobillo	22,5	22,5	22,6	22,6	22,7	22,8	22,8	22,9	22,9	23,0	23,1	23,1	23,2	23,2	23,3
34	Longitud interna pierna	75,6	75,2	74,7	74,3	73,8	75,4	75,0	74,6	74,1	73,7	75,3	74,8	74,4	73,9	73,5
35	Longitud externa pierna	101,6	100,9	100,2	99,6	98,9	101,5	100,8	100,3	99,8	99,1	101,5	100,9	100,5	99,8	99,1
36	Longitud externa pierna hasta tobillo	94,1	93,5	92,8	92,3	91,6	94,0	93,4	92,9	92,4	91,8	94,0	93,5	93,1	92,4	91,7
37	Distancia cintura-rodilla	57,0	56,6	56,1	55,7	55,3	57,0	56,6	56,2	55,7	55,3	57,0	56,6	56,2	55,7	55,3

CONTORNO PECHO	Referencia	88					92					96					100				
	Intervalo	86-90					90-94					94-98					98-102				
CONTORNO CINTURA	Intervalo	71-75	73-77	75-79*	77-81	79-83	75-79	77-81	79-83*	81-85	83-87	81-85	83-87*	85-89	87-91	89-93	85-89	87-91	89-93*	91-95	93-97
1	Estatura	162,6	162,0	161,3	160,7	160,0	162,8	162,2	161,5	160,9	160,2	162,3	161,7	161,0	160,4	159,7	162,5	161,8	161,2	160,5	159,9
2	Altura séptima cervical	138,9	138,3	137,8	137,3	136,8	139,1	138,6	138,1	137,5	137,0	138,8	138,3	137,8	137,3	136,7	139,0	138,5	138,0	137,5	137,0
3	Altura delantera de cuello	132,8	132,2	131,6	131,1	130,5	133,1	132,5	131,9	131,3	130,7	132,7	132,1	131,5	131,0	130,4	133,0	132,4	131,8	131,2	130,6
4	Contorno cuello	33,1	33,5	33,8	34,2	34,6	34,0	34,3	34,7	35,1	35,5	35,2	35,6	36,3	36,8	37,2	36,5	36,9	37,3	37,7	38,2
5	Contorno brazo superior	27,7	27,9	28,1	28,4	28,6	28,7	28,9	29,1	29,3	29,6	29,8	30,1	30,3	30,6	30,8	30,8	31,1	31,3	31,6	31,9
6	Contorno muñeca	14,8	14,8	14,9	15,0	15,1	15,1	15,2	15,3	15,3	15,4	15,5	15,6	15,7	15,8	15,8	15,9	15,9	16,0	16,1	16,2
7	Distancia cuello-cadera	56,4	56,2	55,9	55,7	55,5	56,4	56,2	56,0	55,8	55,5	56,2	56,0	55,8	55,6	55,3	56,2	56,1	55,8	55,6	55,3
8	Longitud brazo	54,4	54,3	54,2	54,0	53,9	54,6	54,5	54,4	54,3	54,1	54,7	54,6	54,5	54,3	54,2	54,9	54,8	54,7	54,6	54,4
9	Longitud brazo superior	30,2	30,2	30,2	30,1	30,1	30,3	30,3	30,2	30,2	30,2	30,4	30,3	30,3	30,3	30,2	30,4	30,4	30,4	30,3	30,3
10	Longitud antebrazo	24,2	24,1	24,0	23,9	23,8	24,3	24,2	24,1	24,0	24,0	24,3	24,3	24,2	24,1	24,0	24,5	24,4	24,3	24,2	24,1
11	Longitud cuello-cintura sobre el pecho	43,8	43,8	43,7	43,7	43,7	44,4	44,4	44,4	44,3	44,3	45,0	45,0	45,0	44,9	44,9	45,7	45,7	45,6	45,6	45,6
12	Caída de pecho	27,8	28,0	28,1	28,2	28,4	28,9	29,1	29,2	29,3	29,5	30,2	30,3	30,4	30,6	30,7	31,3	31,4	31,5	31,7	31,8
13	Contorno bajo-pecho	74,4	75,3	76,0	76,8	77,7	77,6	78,7	79,5	80,3	81,1	81,9	83,1	83,9	84,7	85,5	85,4	86,3	87,4	88,3	89,1
14	Contorno pecho	88,0	88,0	88,0	88,0	88,0	92,0	92,0	92,0	92,0	92,0	96,0	96,0	96,0	96,0	96,0	100,0	100,0	100,0	100,0	100,0
15	Separación pecho	18,0	18,0	18,1	18,1	18,1	18,7	18,7	18,8	18,8	18,8	19,4	19,5	19,5	19,5	19,6	20,1	20,2	20,2	20,2	20,3
16	Longitud axila-cintura	23,9	23,8	23,6	23,5	23,3	23,6	23,5	23,3	23,2	23,0	23,2	23,0	22,9	22,7	22,6	22,8	22,7	22,6	22,4	22,3
17	Anchura espalda	34,0	34,0	34,1	34,2	34,3	34,8	34,8	34,9	35,0	35,1	35,6	35,7	35,8	35,9	36,0	36,4	36,5	36,6	36,7	36,8
18	Longitud cuello-axilas	13,1	13,1	13,1	13,0	13,0	13,4	13,4	13,4	13,4	13,4	13,8	13,7	13,7	13,7	13,7	14,1	14,1	14,1	14,0	14,0
19	Longitud trasera cuello-cintura	39,6	39,6	39,5	39,6	39,5	39,6	39,6	39,6	39,6	39,6	39,7	39,7	39,7	40,3	40,3	39,8	39,8	40,4	40,4	40,4
20	Longitud hombro	13,7	13,6	13,5	13,4	13,3	13,8	13,7	13,6	13,5	13,4	13,8	13,7	13,6	13,5	13,4	13,9	13,8	13,7	13,6	13,5
21	Anchura hombros	36,8	36,7	36,7	36,6	36,6	37,5	37,4	37,4	37,4	37,3	38,2	38,1	38,1	38,0	38,0	38,9	38,8	38,8	38,8	38,7
22	Contorno cintura	73,0	75,0	77,0	79,0	81,0	77,0	79,0	81,0	83,0	85,0	83,0	85,0	87,0	89,0	91,0	87,0	89,0	91,0	93,0	95,0
24	Contorno caderas	95,6	96,2	96,9	97,6	98,4	98,0	98,7	99,4	100,2	101,0	101,2	102,0	102,8	103,7	104,5	103,8	104,7	105,5	106,4	107,3
25	Contorno cadera inferior	97,0	97,6	97,9	98,8	99,4	98,9	100,0	100,5	101,1	101,5	102,2	102,5	103,0	103,5	104,0	104,1	104,6	105,3	105,6	106,1
26	Tiro delantero	26,4	26,4	26,5	26,5	26,6	26,8	26,8	26,9	26,9	27,0	27,3	27,3	27,4	27,5	27,5	27,7	27,8	27,8	27,9	28,0
27	Tiro trasero	31,0	31,1	31,2	31,2	31,3	31,7	31,8	31,9	32,0	32,0	32,6	32,6	32,7	32,8	32,9	33,3	33,4	33,5	33,5	33,6
28	Longitud cintura-nalgas	19,1	18,8	18,4	18,1	17,9	19,0	18,6	18,3	18,1	17,8	18,5	18,2	18,0	17,6	17,3	18,4	18,2	17,8	17,5	17,2
29	Longitud trasera cintura-nalgas	18,5	18,2	18,0	17,7	17,4	18,4	18,2	17,9	17,7	17,4	18,1	17,8	17,6	17,3	17,0	18,0	17,8	17,5	17,2	16,9
31	Contorno muslo	56,7	56,9	57,2	57,4	57,6	58,0	58,2	58,4	58,6	58,8	59,5	59,7	59,9	60,1	60,3	60,8	61,0	61,2	61,4	61,6
32	Contorno rodilla	35,6	35,8	36,1	36,3	36,5	36,4	36,6	36,9	37,1	37,3	37,4	37,7	37,9	38,1	38,4	38,2	38,5	38,7	39,0	39,2
33	Contorno tobillo	23,4	23,4	23,5	23,6	23,6	23,7	23,7	23,8	23,9	23,9	24,1	24,1	24,2	24,3	24,3	24,4	24,4	24,5	24,6	24,6
34	Longitud interna pierna	75,1	74,6	74,2	73,8	73,3	74,9	74,5	74,0	73,6	73,2	74,3	73,9	73,4	73,0	72,6	74,1	73,7	73,3	72,8	72,4
35	Longitud externa pierna	101,8	101,2	100,3	99,8	99,3	101,6	101,0	100,5	100,0	99,4	101,2	100,7	100,0	99,5	98,9	101,3	100,7	100,2	99,6	99,0
36	Longitud externa pierna hasta tobillo	94,3	93,7	92,9	92,4	91,9	94,2	93,6	93,1	92,6	92,0	93,7	93,3	92,6	92,2	91,6	93,8	93,3	92,8	92,2	91,6
37	Distancia cintura-rodilla	57,0	56,6	56,2	55,7	55,3	57,0	56,6	56,2	55,7	55,3	56,6	56,2	55,8	55,3	54,9	56,6	56,2	55,8	55,3	54,9

Fig 4. Example of sizing tables

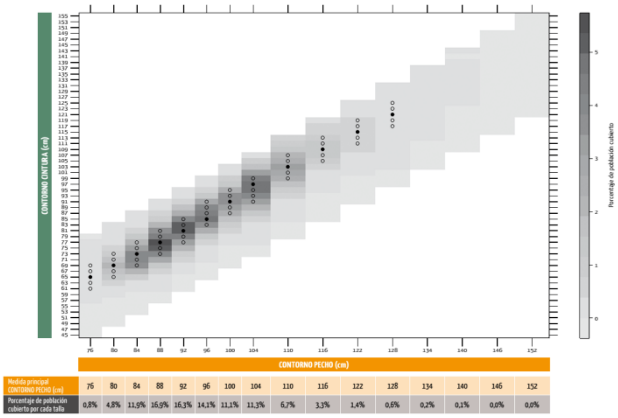

Fig. 5. Example of application of ISO/DIS 8559-2 to Spanish female population (Waist vs. Hips)

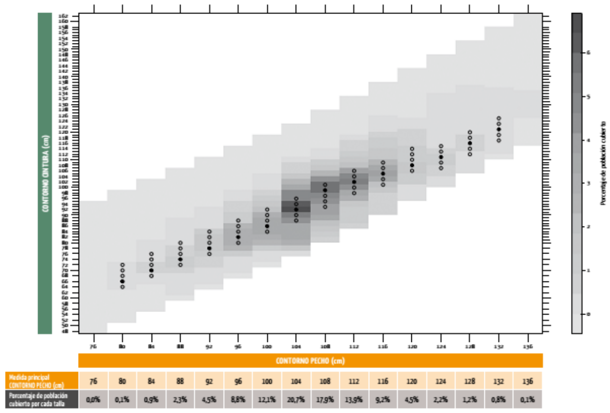

Fig. 6. Example of application of ISO/DIS 8559-2 to Spanish population (Waist vs. Chest)

Fig. 7. Examples of mini-mannequins of the Spanish male population

Fig. 8. Examples of mini-mannequins of the Spanish female population

4. Transfer of results to industry (children data)

Childrenswear ergonomic design processes and size definition have several differences with regard to adult apparel. Firstly, childrenswear size designation is usually labelled in ages, which is not a body measurement, so it is usually related to a concrete body height per age, which does not necessarily have to be close to a child of that age, due to the high variability of height by age in children.

Moreover, the use of reference mannequins for patternmaking and fit checking of samples is much more spread across childrenswear manufacturers than in adults'. This is because children's body change rate (e.g. due to growing) is much higher than in adults, and thus manufacturers cannot use real models for pattern creation and for checking samples if they want to maintain product sizing traceability along several years. Those manufacturers that do not use mannequins, at least use size tables of body dimensions based on aggregated statistics.

In Spain, the National Association of Childcare Products (ASEPRI) created in 1999 its own "standardized" sizing system, which is commercialized both as a table of body dimensions by size (i.e. 12 for babies and 14 for children) and as a collection of physical mannequins [19] that match these measurements (fig. 10). These two products were created based on aggregated statistics from different measurement-based anthropometric studies around the world [20]. Since 2006, the French Institute for the Textile and Clothing Industries (IFTH) also makes available to French companies the Children "Anthropometric Box Set" based on the French National survey. The most commonly used size mannequin collection is internationally is Formax® by CadModelling [21] and AlvaFORM [22], which offers an array of standard collections created from parametric body shapes based on measurement statistics from standards (i.e. ASTM) and from anthropometric studies (i.e. US, France, UK, China, Mexico and Germany). Alvanon also provides services for the creation of made-to-measure mannequins to companies based on body dimensions. 3D Human Modelling [23] from Konings & Kappelhoff and TUDelft commercializes digital children mannequins for general ergonomic design.

Based on the measurement and 3D data gathered in the Anthropometric Study of Spanish Children under KidSize [24] and AEI Infancia [25] projects, IBV created two tools for childrenswear and other childcare product manufacturers: the Spanish Size table by body dimensions and their corresponding collection 3D digital mannequins (only from 3 y.o.).

Tools based on Spanish children data (size tables)

On the one hand, IBV created a table of body dimensions by size, where each size is defined by a stature range and it is indicatively related to an age. Stature ranges were defined according to existing ASEPRI size ranges. Moreover, for each size, different percentiles (P05, P25, P50, P75 and P95) are provided. The 19 measurements gathered for babies (aged 0 to 36 months) were included in the size tables. Among the 65 measurements gathered for children aged 3 to 12 y.o., 35 were included (fig. 9).

	Size 92 cm (~2 y.o.)					…	**Size 152 cm (~12 y.o.)**				
	P05	P25	**P50**	P75	P95	…	P05	P25	**P50**	P75	P95
1. Height											
2. Cervicale height											
3. Outside leg length											
…						…					
35. Total crotch length											
36. Crotch length front											
37. Crotch length rear											

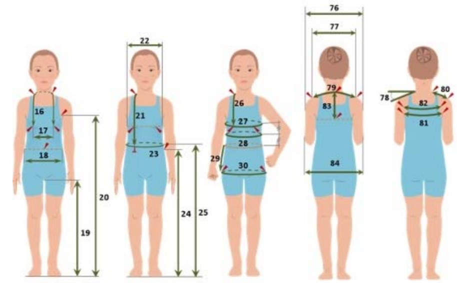

Fig. 9. Example of children size tables and graphical description of measurements

Part of the results from this table have already been used to update the 12 baby body dimensions and 14 children body dimensions of ASEPRI size tables, and to extend the number of body dimensions by 6 and 10 respectively (18 for babies in total and 24 for children).

Tools based on Spanish children data (digital mannequins IBV/KidSize)

Based on the table of body dimensions by size (Percentile 50), IBV created a collection of digital size mannequins following the 1D to 3D data-driven shape recreation methods [**Error! Bookmark not defined.**], in this case using 20 of the 24 measurements included in ASEPRI size tables. IBV created mannequins from 92 cm (~2 y.o.) to 152 cm (~12 y.o.). Some of the mannequins from the resulting collection are presented in fig. 11.

Fig 10. current ASEPRI mannequin collection digitized (from 3 y.o. to 10 y.o.)

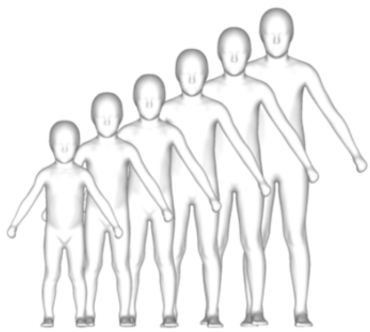

Fig 11. Proposed IBV/KidSize mannequin collection digitized (from 3 y.o. to 10 y.o.)

The resulting mannequins from our study (herein IBV/KidSize mannequins) where compared to current ASEPRI collection in terms of shape. This comparison showed that despite having been made from a very similar measurements definition, the mannequins corresponding to the same size from each collection have clearly different shapes. The comparison study consisted of a measurement-based comparison and a graphical comparison of 3D shapes and 2D contours at three critical body measurements (i.e. chest, waist and hips) made for mannequins corresponding to the same statures.

The results of the measurement study showed important differences in value (ranging from 5 to 25%) for some measurements, namely shoulder length, arm length, back width and knee height. Based on the graphical comparison (2D and 3D), it was concluded that the body shapes of IBV/KidSize mannequins had a more human morphology than ASEPRI ones, in particular at the trunk shape (i.e. lumbar and dorsal curves; and chest, waist and hips), head shape, armpit region and limb proportions.

Some comparative images are provided for the mannequins of 104 cm (~4 y.o. unisex) and of 152 cm (~12 y.o. female).

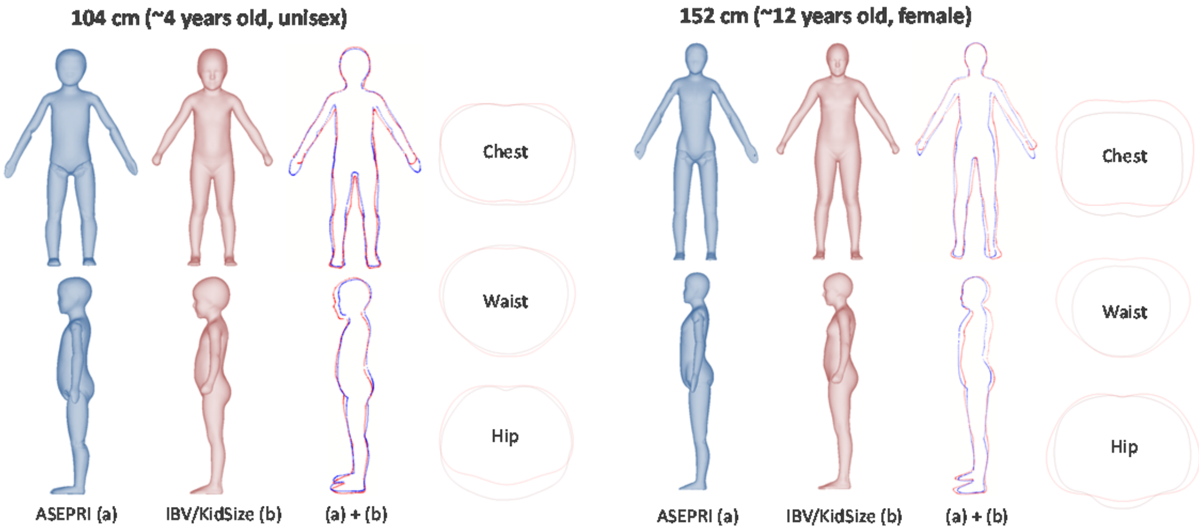

Fig. 11. Example of 2D contour and 3D shape comparison between ASEPRI and IBV/KidSize mannequins

4. Conclusions and future work

Since the first 3D large anthropometric surveys conducted in 1999, the resource investment on this kind of studies has been huge and it industry uptake has not yet been comparable. One of key factors for the actual absorption of results is the implication and the commitment of the sector (i.e. the companies and the lobby representatives) in the surveys and in the development of the tools addressed to them. In the case of the tools created from the Spanish data, it was successful because both KidSize and Sizing-SUDOE where projects led by sectoral associations. A second key factor of success for the technology/knowledge transfer is that the tools developed have a progressive level of complexity. This means providing entry level tools, which usually can be made available for free and can be uptaken by any company, independently of their technological development level and the knowledge/control of their processes and products. An also providing more advanced tools like the complex bi-dimensional size tables or the size representative mannequins (physical or virtual). Moreover, it is critical that results are connected and compliant with related standards either in force or under development.

In a global market context where most companies are (or aim at) selling in many different countries, the fact that anthropometric databases are in most cases national, makes them less attractive to companies. However, the complexity of the projects that were built to gather them, in most of the cases made of complex consortia including private and public agents, make that the trade, exchange or share of the data also becomes complex, especially it is for commercial purposes. Good examples of success in this sense are AlvaFORM [22] mannequins from Alvanon and the iSize portal [26] from Human Solutions Group, where measurement statistics from different countries can be extracted and could help in the creation size charts. In this sense, it is expected that Spanish data will be available at the portal by 2016 and that a selection of the Spanish population mannequins are manufactured at natural scale. However, the extension of these type of tools beyond measurements to the actual use of 3D data, despite having been technically demonstrated [2,18], it is being slowed down and hampered by the aforementioned non-technical difficulties.

Furthermore, the fact that market targets of apparel companies are becoming more concrete in terms of sociodemographic segmentation at the same time as global makes that pre-defined data, pre-defined mannequins, books and aggregated statistics are not always the best answer to their needs. In this context, it is important the role of companies and academia that can act as “curators” of the vast anthropometric data that is available and provide tailored services and analyses that are beyond the knowledge and technical capabilities of the apparel companies.

Finally, the results of the presented studies show that mannequin collections created by data-driven methods based on 3D databases can provide morphologically correct and more realistic mannequins that would constitute a better tool for product design. The next challenges to be faced consist of taking advantage of the new manufacturing technologies available (i.e. additive manufacturing) in order to be able to create physical mannequins in a fast, cheap and sustainable way.

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