

Design analysis of reusable surgical clothes and new product development

Assist. Prof. **Arzu Sen Kilic**, PhD

Prof. **Ziynet Ondogan**, PhD

Assoc. Prof. Dr. **Esra Dirgar**, PhD¹

Ege University School of Fashion and Design, Bornova-Izmir, Turkey

¹Ege University Bergama Technical and Business College, Bergama-Izmir, Turkey

e-mail: dirgare@gmail.com

Received December 26, 2018

UDC 687.017

Professional paper

Surgical gowns are used to prevent viruses from passing through to the patient and also to keep medical staff away from blood pathogen exposures. Surgical gowns must prevent infections and diseases and provide adequate freedom to move as well. They must fit well and must not restrict movement. In this study, it was aimed to determine the model properties of the garment worn by surgical staff in surgical environments. For this purpose, for product development, a detailed design analysis was carried out on surgical garments used in hospitals in Izmir. As a result of this analysis, suggestions were made about the model properties and measurements of surgical clothes used by the staff in surgical environments.

Keywords: *surgical clothes, reusable, design analysis, measurement analysis*

1. Introduction

Surgical gowns are traditionally worn to protect the surgical team from bloodborne pathogens (HIV, Hepatitis B, Hepatitis C) and to protect patients from contamination by the surgical team [1].

It is known that both reusable and disposable surgical clothes and drapes are the nearest materials to the skins of patients and the surgical team and also to the operational area. Therefore, these materials used for both the patient and surgical staff are required to have some protective properties [2]. Among these properties, pore size of the surgical garment, liquid repellency - liquid-tightness and air permeability appear to be features to be considered [3].

Surgical clothes should also meet the ergonomic needs besides these properties. In other words, these clothes are expected to be comfortable and functional, allow for sufficient freedom of movement and adapt to changes in heat and prevent sweating. Freedom of movement, sweating, physiological relevance of working conditions in surgical clothes, must comply with asepsis and ergonomic factors should be taken into account when designing this type of clothes [4].

Apparel garments must meet at least minimal functional requirements like color and structure, including being supported by the body and allowing some degree of body movement. Therefore, it is important that surgi-

cal garment should not restrict body movement. Successful creations of functional apparel products requires a disciplined, structured approach to design and development. An effective, integrated approach progresses through investigation of the design problem, delineations of design requirements and critical analysis of those requirements before arriving at a design solution [5].

The surgical clothes used in a surgical environment consist of scrub sets and surgical gowns to be worn over these sets [2, 6]

There have been many studies on surgical gowns. However, these studies generally focus on the types of fabrics used in surgical gowns and their protective properties.

Plumlee and Pittman (2002) applied design analysis to 13 disposable and 2 reusable surgical gowns. With this analysis, model properties of surgical garments were examined and measurement analyzes were performed.

Tab.1 Representation of the samples

Name of the manufacturers	Name of the models
A	A1
A	A2
B	B
C	C
D	D1
D	D2

They designed an analysis strategy to evaluate the suitability of surgical gowns [5].

Kiliç A. et al. (2014) investigated the material structures of reusable scrub sets and reusable surgical gowns used in surgical operations [6].

Rutala ve Weber (2015), examined the use of gowns and drapes in healthcare facilities, including the characteristics, costs, benefits, and barrier effectiveness of single-use and reusable products [7].

This study was performed in order to determine model properties of functional surgical garments to be worn in

surgical environment. For this purpose, samples were taken from the surgical garments used on hospitals in Izmir and design analysis was applied to these garments. As a result of this analysis, suggestions were made about the model properties and the dimensions of surgical clothes.

2. Methodology

This study was carried out in order to determine the model properties of surgical clothes used in surgery. Surgical garments obtained from five different surgical garment manufacturers were used in this study. For the selection of these companies, garment manufacturers in and around İzmir where the hospitals purchased surgical garments from were investigated.

Surgical clothes considered in the study consist of surgical scrub sets (V neck short sleeved top and pants) and surgical gowns that is worn on them. Sleeves and front sides of surgical gowns are of critical importance in terms of barrier performance of the garment. Therefore, in order to strengthen the barrier effect, some manufacturers have termed their product as reinforced products and they have added a second layer of fabric on the front and arms of gowns onto the base fabric.

In this study, surgical garments to be examined are represented by the letters (A, B, C,D, E) according to the



Fig.1 Scrub sets used in surgical operations



Fig.2 Surgical gown with one-piece front



Fig.3 Back view of surgical gown



a)



b)

Fig.4 Reinforced surgical gown: a) from the yoke, (b) under the yoke

Tab.2 General appearance and reinforced parts of surgical gowns

Model	Reinforced parts	Non-reinforced part
A1	-	Front – one piece
A2	Under yoke (1/2) - 1/2 sleeve	-
B	-	Front – interval
C	Under yoke (1/2) - 1/2 sleeve	-
D1	From neck - 1/2 sleeve	-
D2	Under yoke (1/2)	-
E	Front – Sleeves	-

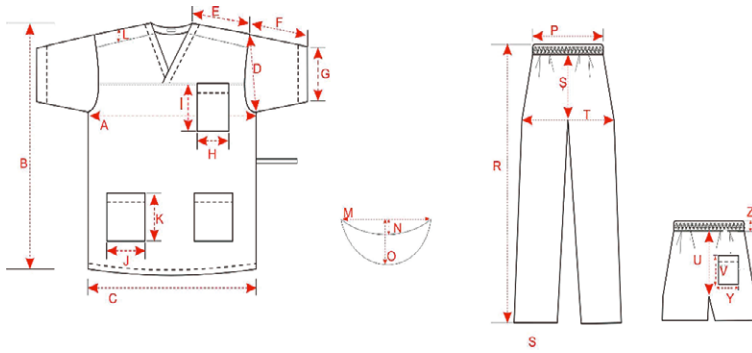


Fig. 5 Technical drawings of the surgical scrub sets

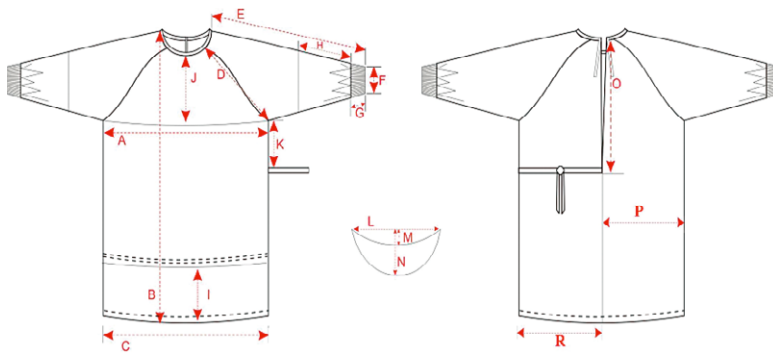


Fig.6 The technical drawing of raglan sleeved surgical gowns

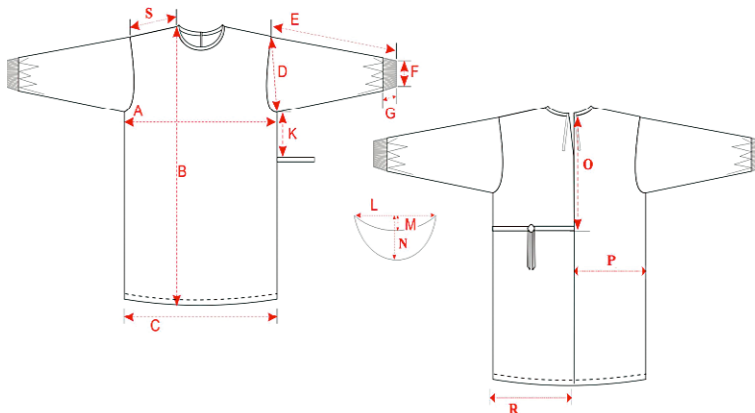
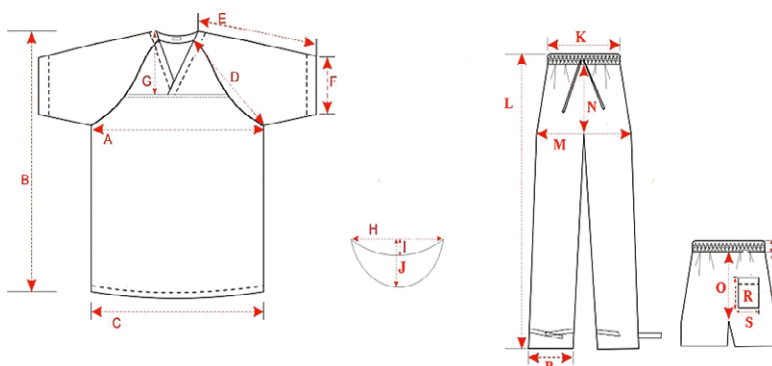


Fig.7 The technical drawings of surgical gowns with set-in-sleeves



Sl.8 Recommended surgical scrub sets

company they were produced. Manufacturers used a single model for surgical scrub sets. However, two manufacturers (A and D) used two different models for surgical gowns. Therefore, in order to distinguish between these gowns were added numbers next to the letters representing each manufacturer (Tab.1).

According to the purpose of the research, to determine the properties of surgical gowns that provide protection and comfort, design requirements were analyzed, product's technical pictures were drawn using these requirements and measurements of the garments were taken. The main steps of this approach are listed as follows:

2.1. Design analysis

First of all, design analysis was conducted for the evaluation of the existing products. Design analysis consists of two steps: Structural analysis and measurement analysis. Structural analysis is the first step in design analysis. It is used to determine the market's characteristics and to determine the design features of existing products [5]. The samples that are provided in this study were examined in terms of model properties in structural analysis.

Following this in the second step of the design analysis, measurements of surgical scrub sets and surgical gowns were obtained by a tape measure. Prior to completing measurements, the surgical gowns were tied closed. By the result of measurement analysis, the minimum, maximum and the average value of each measure of the existing samples were determined.

2.2. Design development

Properties of functional clothes were defined and technical drawings were made considering the requirements determined by design analysis. Then with measurement analysis of the existing surgical clothes, measuring process was carried out on the designed garment. The measurement

process benefited from the table that contains the minimum, maximum and the average value of each measure of the samples. Mean values in this table, were considered as the size of the designed garment.

3. Results

The findings obtained from the design analysis is as follows.

Structural analysis

Surgical scrub sets consist of a short sleeve V-neck scrub top and scrub pants with an elastic waist (Fig.1). Surgical scrub sets used in this study were determined to have the same model properties. 2 cm wide facing is used in the neck of the top of scrub sets. Sleeves of all types of top garments are folded in 2 cm. Three pockets are added on to the top garment with yoke. One of the them is added below the yoke and the others onto the bottom of the top. One pocket is also located on the back side of the pants.

Surgical gowns worn in surgical environments consist of four main parts: Front, back, arms and cuffs. The design analysis of surgical gowns has shown that, contrary to surgical scrub sets, manufacturers produce different models of surgical gowns. Surgical gowns are evaluated in terms of appearance, barrier function, structures of arms and using stitches in the design analysis.

Appearance: The fronts for Model A1 and Model E are designed in one piece. (Fig.2). The fronts of Model A2, Model C, Model D1 and Model D2 are constructed from 3 pieces. Unlike them the fronts of Model B are constructed with yoke.

The backs of surgical gowns are composed of two overlapping panels (Fig.3). Usually, the surgical gown is designed in a way that the right part of the garment will be on the left part and larger than it. The width of these pieces is arranged in different sizes by the company. Only in Model B these parts are equal.

Tab.3 The measurements of scrub sets

Measurements (Medium size)(cm)		A	C	D
A	Chest	62	59	58
B	Length from shoulder	76	76	71
C	Hem width	62	59	58
D	Armhole	27	28	26
E	Shoulder length	20	18	18
F	Sleeve length	21	25	24
G	Sleeve width	24	20	21
H	Top pocket width	11	14	12
I	Top pocket length	13	15	13
J	Bottom pocket width	16	16	16
K	Bottom pocket length	21	17	16
M	Neck opening	17	17	22
N	Back neck drop	3	3	5
O	Front neck drop	15	15	12
P	Waist (with elastic)	30	30	30
R	Outside leg with waistband	109	109	111
S	Leg width	22	20	22
Ş	Front rise	35	36	36
T	Hip width	54	62	55
U	Back rise	40	42	42
V	Back pocket width	14	14	15
Y	Back pocket length	15	15	16
Z	Waistband	3.5	3.5	3

Tab.4 Measure evaluation of surgical scrub sets

Measurements (Medium size) (cm)		Lower limits	Upper limits	Mean
A	Chest width	58	62	60
B	Length from shoulder	71	76	73.5
C	Hem width	58	62	60
D	Armhole	26	28	27
E	Shoulder length	18	20	19
F	Sleeve length	21	25	23
G	Sleeve width	20	24	22
H	Top pocket width	11	14	12.5
I	Top pocket length	13	15	14
J	Bottom pocket width	16	16	16
K	Bottom pocket length	21	16	18.5
M	Neck opening	17	22	19.5
N	Back neck drop	3	5	4
O	Front neck drop	12	15	13.5
P	Waist width (elastic)	30	30	30
R	Outside leg with waistband	109	111	110
S	Leg width	20	22	21
Ş	Front rise	35	36	35.5
T	Hip width	54	62	58
U	Back rise	40	42	41
V	Back pocket width	14	15	14.5
Y	Back pocket length	15	16	15.5
Z	Waistband	3	3.5	3.5

Tab. 5 Measurement table of surgical gowns

Measurements (cm)		A1	A2	B	C	D1	D2	E
A	Chest width	73	73	86	68	76	76	74
B	Length from shoulder	130	130	142	132	138	131	140
C	Hem width	73	73	86	68	76	76	74
D	Armhole	27	27	30	35	41	41	41
E	Sleeve length	69	69	68	82	87	87	90
F	Sleeve width	9	9	8	8	8	8	8
G	Cuff depth	8	8	7	8	8	8	9
H	Sleeve tape width	-	45	-	55	32	32	-
I	Bottom tape width	-	42	-	32	40	57	-
J	Yoke width	-	30	24	12	22	12	-
K	Tie position fr underarm	20	20	-	24	12	12	20
L	Neck opening	20	20	18	19	20	20	20
M	Back neck drop	3	3	3	3	5	5	5
N	Front neck drop	9	9	10	9	10	10	10
O	Tie position from centre back	50	50	-	48	42	42	50
P	Width of right back part	47	47	43	50	49	49	63
R	Width of left back part	32	32	43	32	34	34	48
S	Shoulder length	20	20	28	-	-	-	-

Tab.6 Measure evaluation of surgical gowns

Measurements (cm)		Lower limit	Upper limit	Mean
A	Chest width	68	86	77
B	Length fr shoulder	130	142	136
C	Hem width	68	86	77
D	Armhole depth	34	41	37.5
E	Sleeve length	82	86	84
F	Sleeve width	8	9	8.5
G	Cuff width	8	8	8
H	Sleeve tape width	32	55	43.5
I	Hem tape width	32	57	44.5
J	Yoke width	12	30	21
K	Tie position fr underarm	12	20	16
L	Neck opening	20	23	21.5
M	Back neck drop	3	5	4
N	Front neck drop	9	10	9.5
O	Tie position fr centre back	42	50	46
P	Width of right back part	43	63	53
R	Width of left back part	32	48	40
S	Shoulder length	20	28	24

Barrier Function: The material used for the reinforcement in Model D2 is combined from the neck like a yoke. (Fig.4a). The materials used for the reinforcement in Model A2, Model C and Model D1 are made of self fabric and are combined under the yoke (Fig-4b). The front part and sleeves in Model E are made of reinforced fabric only.

Reinforced parts with barrier effect and general appearances of surgical gowns in the research are included in Tab.2.

To cover the body in surgical gowns, 1 cm wide self-binding is attached to the right and left back panels as ties. Only in Model E, drawstring is used for covering the body instead of binding.

Structures of sleeves: A majority of surgical gowns examined were raglan sleeved. But Model A1, Model A2 and Model B had set-in sleeves. The sleeves consist of two pieces including the lower and upper pieces. Also it was added reinforcing fabric as a second layer on the sleeves of surgical gowns used in an operation in which barrier effectiveness is important. Sleeves in Model E are single ply and are made from reinforced fabric.

Rib cuff compatible with the material of body fabric are added into the sleeve edges of surgical gowns.

Seam Properties: 4-thread chain stitch is usually used in joining shoulders, attachment of the sleeves, closing sleeves and side seam and in joining cuff. Also, lock stitch is used for folding hem, inserting pockets and for top-stitching.

Measurement analysis

In this part of the study, there are technical drawings and measurement tables of the samples of surgical clothes.

Technical drawings of the surgical scrub sets worn in surgical environments are shown in Fig.5.

The measurements of scrub sets according to the firms are given in Tab.3.

The mean values were reached by lower and upper values of the measurements of surgical scrub sets. These values are given in Tab.4.

Fig.6 includes the technical drawings of raglan sleeved surgical gowns.

Fig.7 includes technical drawings of surgical gowns with set-in-sleeves.

Measurements of surgical gowns of the firms are given in Tab.5.

The mean values were reached by lower and upper values of the measurements of surgical gowns. These values are given in Tab.6.

4. Discussion

Clothes used in the surgical environment include surgical scrub sets and surgical gowns worn on them. Recommendations on functional clothes

to be developed benefiting from the results of the design analysis are listed below.

Recommended top neck to be worn in the surgical environment is V-neck that can be removed easily without causing contamination and the front side of top is advisable to have a two-piece yoke. It is also recommended that a facing is attached V neck for cleaning.

The movement of the surgical staff in the surgical environment is examined. It is determined that the surgical staff usually move their arms and the movement of the arms are in the horizontal direction. With respect to this observation, the form of the garment sleeve is recommended to be designed as a short raglan sleeve. If a pocket is to be attached to the top of the scrub sets, it may open a needle hole which may cause fluid penetration. Thus no pocket is recommended to be attached.

A selfbinded tie suggested to be placed on the waist of the pants of scrub sets. In this way, pants will fit the body of the surgical staff. Self binded ties are suggested for the lower parts of trouser as they make easier to adjust leg width. Pockets are also attached to the back of the pants in order to meet the need for pockets. Fig.8 includes technical drawings of recommended surgical scrub sets.

When manufacturing surgical gowns and surgical scrub sets it is appropriate to work in three different body sizes both for men and women. This allows for providing the surgical staff with appropriate garment sizes. The mean values given in Tab.4 were adopted as medium size of the recommended surgical scrub sets. The measurements of the other sizes were obtained using these values (Tab.7).

For a surgical gown which is the most important protector in a surgical environment, the front side of the garment is recommended to be produced as one-piece and the back part of the garment is recommended in two-pieces. The two-piece design of the

back side of the garment aims to achieve a breathable garment, to maintain sterilization of the clothes

and to provide easy to wear garments. At the design stage, considering that the pinhole will reduce the barrier

Tab.7 Measurements of recommended surgical scrub sets

Measurements (cm)		S	M	L
A	Chest width	56	60	64
B	Length from shoulder	70	74	78
C	Hem width	56	60	64
D	Armhole	26	27	28
E	Shoulder length	39	41	43
F	Sleeve width	21	22	23
G	Neck depth	15	16	17
H	Neck width	19	20	21
I	Back neck drop	2	2	2
J	Front neck drop	13	14	15
K	Waist (with elastic)	52	56	60
M	Hip	106	110	114
N	Front rise	20	21	22
O	Back rise	35	36	37
P	Leg width	52	58	62
R	Pocket length	40	41	42
S	Pocket width	15	15	15
T	Waistband	3.5	3.5	3.5

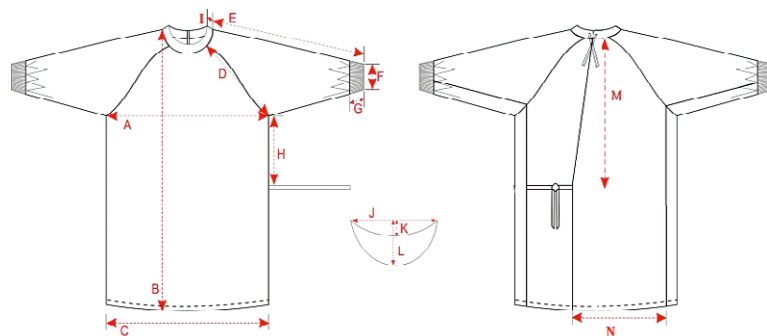


Fig.9 Recommended surgical gowns

Tab.8 Measurement table of recommended surgical gowns

Measurements (cm)		S	M	L
A	Chest	73	77	81
B	Length	132	136	140
C	Hem width	73	77	81
D	Armhole	40	41	42
E	Sleeve length	82	84	86
F	Sleeve width	8	9	10
G	Cuff width	8	8	8
H	Tie position fr underarm	16	16	16
I	Neck piping width	1.5	1.5	1.5
J	Neck width	21	22	23
K	Back neck drop	2	2	2
L	Front neck drop	6	7	8
M	Tie position fr centre back	46	46	46
N	Width of right back part	49	53	57
O	Width of left back part	36	40	44

gowns, unnecessary partitions are avoided. Also with the same idea, front part of the garment is designed to be wider than the back part. Thus, it is provided that the side seams turn to the back.

The recommended neck design for surgical gown is O-neck. Also fixing self binding in 1.5 cm wide to the neckline is recommended not to irritate the skin and to absorb sweat off the surgeon.

The closing of the neck is advised to be adjustable by the ties.

To close the body of surgical gowns, 1 cm self-bound ties are attached to the back parts. In order to complete the line, one internal tie and one external tie are attached as well. One of the back parts of the surgical gown is designed wider than the other. One of these parts is combined with the tie in the inner side seam and the other part is combined with the tie in the outer side seam. Therefore, back closing is completed.

Surgical staff often move their arms in the horizontal direction. Therefore, to ensure the ease of movement, sleeves of surgical gowns are proposed to be designed as a one-piece raglan sleeve. Cuff rib is attached to the sleeves in order not to disturb the surgeon, particularly in long-term operations. This fabric is made of 75% Cotton (30/1) 25% Nylon (90/1). Fig.9 includes technical drawings of recommended surgical gowns.

Surgical gowns were studied in three different body size like surgical scrub sets. The mean values given in table 6 were adopted as medium size of the recommended surgical gowns. The measurements of the other sizes were obtained using these values (Tab.8).

In the seam, according to the direction of the joined parts, flexibility properties may be different depending on the stitch type used. Therefore, in the selection of the sewing type, the direction of the warp and weft of

garment parts are necessary to consider [2].

Most moving parts of the body of surgical staff are the arms during an operation. These movements of the arms are especially extending forward and moving up and down. When the arm is lifted up, seams under the armhole and side seams are affected and when the arm is extended forward, armhole line is affected. So, especially stitches used for the attachment of the sleeve to the body, closing sleeves and side seams are considerably important. The attachment seams of the sleeve are formed in a direction toward both in warp and weft directions. In the seam closing sleeves, one side of the seam is in weft direction and the other side of seam is in the warp direction [2]. To obtain a strong connection in weft and warp direction it is recommended to use chain stitch, 3-needle overlock or 4-needle overlock [8]. However chain stitch is thought to be the most appropriate stitch among these seams for a surgical gown. Thus, it would be appropriate to use a flatlock machine for sleeve attachments.

In the operation of closing sleeves, one side of the seam is in weft direction and the other side is in the same weft direction. To obtain a strong stitch in this direction, it is recommended to use 3, 4 or 5 thread overlock stitches [8]. But for surgical gown, flat felled seam is recommended for assembling of the sleeves for safety purposes.

In the side seams, both sides of the seam is in the weft direction. So for closing side seams of surgical gowns it is recommended to use flat felled seam machine. It is also recommended to close the back of the seam line with a liquid-impermeable tape.

5. Conclusion

In this study, design analyses were conducted on a variety of surgical

gowns and surgical scrub sets and new model features for surgical gowns and surgical scrub sets have been recommended with respect to the data obtained from the analysis. This study is expected to provide insight into surgical clothing manufacturers for future studies.

References:

- [1] Suprun N., V. Vlasenko, Y. Ostrovetchkhaya: Some aspects of medical clothing manufacturing, *International Journal of Clothing Science of Technology* 15 (2004) ¾, 224-230
- [2] Sen A.: Cerrahi Ortamda Cerrahi Personelin Giyebileceği Özel Giysi Geliştirilmesi, 2005, Unpublished PhD theses, Ege University, İzmir
- [3] Aktuğlu Öndoğan Z., O. Pamuk: Cerrahi ortamda kullanılan giysilerin genel özellikleri, *Tekstil Konfeksiyon* (2002) Ege Üniversitesi Tekstil ve Konfeksiyon Araştırma-Uygulama Merkezi Yayını, Yıl. 12, Sayı. 3 S. 153-155
- [4] Ondoğan Z.: Cerrahi giysilerde özellikler, *Tekstil & Teknik Dergisi* (1999) Sayı. 175, s. 76-79
- [5] Plumlee, T. M., A. Pittman: Surgical gown requirements capture: A design analysis case study, *Journal of Textile and Apparel, Technology and Management* Vol 2 (2002) 2, 2-3 p.
- [6] Sen A., Z. Ondoğan, E. Dirgar: A study on material selection of reusable surgical garments, *Industria Textila* (2014) Volume: 65, Issue:2, 210-216 p.
- [7] William A. Rutala, David J. Weber, A Review of Single-Use and Reusable Gowns and Drapes in Health Care, *Infection Control & Hospital Epidemiology* Volume 22, Issue 4, April 2001, pp. 248-257
- [8] Bozkurt B.: Vücut hareketlerinin giysi özellikleri üzerine etkileri, Unpublished doctoral thesis, 1995, İzmir