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PHYSICAL MECHANICAL PROPERTIES OF MEDICAL SOCKS PROPOSED FOR DIABETIC FOOT SYNDROME SAMPLED FROM THE MARKET

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Abstract:

Diabetic disease and its chronic complications is a public health problem that affects millions of people all over the world. Feet diabetics need private care by using appropriate shoes and socks, to avoid friction, sweating and high temperature. Diabetic socks have to attain an effective thermal comfort and higher appraisal performance. To achieve these conditions, the diabetic socks have to attain comfortable fit, no pressure points or seams on fingers, suitable size, classified as spring-summer or autumn-winter and also to avoid high temperature. The specifications of the diabetic socks sold in the market consist of its material combination, size and chemical treatments. No definite physical mechanical properties of diabetic socks are proposed. Diabetic socks taken from the market, with appropriate price, were evaluated for both thermal and non-thermal properties. The tested samples demonstrate a great variability's in the fabric construction and properties. By analyzing the tested socks, the proposed values concerning the properties of diabetic socks for summer and winter are introduced. Moreover, relative geometrical mean of thermal comfort properties was proposed for determining a global measure of diabetic sock properties.

Keywords:

Diabetic socks, knitted construction, knitted hosiery, fabric comfort

1. Introduction

Comfort involves thermal and non-thermal components, and it depends on the wear situations. Thermal comfort is affected by the environment and personal choices and is defined as mind satisfaction with thermal environment.[23,25] There is an inverse relation between thermal conductivity and thermal resistance.[1]

Thermal conductivity along the axis of fibers or yarns is higher than along the transverse direction for all fiber types.[13] Cotton has the best thermal properties and higher thermal resistance; thus, it protects body from temperature difference. While silver fiber gives higher thermal conductivity, cotton/bamboo gives higher thermal absorption and both bamboo and soybean are superior in handle properties.[3] Thermal resistance represents the thermal barrier for wearer. Micro-denier fibers allow low thermal conductivity and higher thermal resistance.[1,6] Bamboo, Soybean protein and SeaCell fibers are naturally antibacterial, biodegradable, UV protectable, bright, soft, smooth, with high moisture absorption capacity and permeability.[7,10,27]. Hollow fibers increase both thickness and fabric thermal resistance.[14]

Yarns with elastane increase the thermal conductivity, thermal resistance and absorptivity, and decrease the water vapor permeability. Compared to cotton, reclaimed fiber has lower thermal conductivity and absorptivity, and higher thermal resistance; it also has higher water vapor permeability. Compared to cotton, no significant results were obtained with elastane reclaimed fiber.[12] Fabric construction contributes about 80% of the thermal levels, different constructions may contribute to the same thermal properties.[16,24] They affect thermal resistance, thermal absorptivity, and relative vapor permeability properties.[3,11] Fabrics with higher air permeability gives lower thermal insulation and higher thermal diffusion.[21] Higher fabric weight for cotton and modal fibers have higher thermal conductivity. Compared to air, more fiber amounts result in higher thermal conductivity.[1]

Knits are comfortable to wear and easy to care for, they are elastic and have stretchy behavior. Also, they shed wrinkles well, have good handle and easily transmit vapor from the body.[17] Higher tightness and lesser loop length increases the bursting strength.[19] Knits with lesser course per cm, finer yarns and longer loop length have higher air permeability due to the larger pores between loops and looser fabric surface.[18] Thermal comfort depends on the natural yarn type and construction. Maximum air permeability is determined at single natural yarn and two natural yarns plated with texture Polyamide or Lycra fibers. Higher thermal conductivity coefficient is obtained when using single natural yarn plated with texture Polyamide and three natural yarns plated with texture Polyamide or Lycra fibers. Furthermore, higher thermal resistance coefficient is obtained when using single natural yarn plated with texture Polyamide and three natural yarns plated with texture Polyamide or Lycra fibers.[9] Socks knitted from natural fibers are preferred for warm climate, while those plated with textured polyamide (PA) and elastane (Lycra) can be chosen for cold weather. Most comfortable socks for winter are those from cotton/SeaCell and bamboo/flax with plated Lycra.[7,8] Compact yarn has higher air and water vapor permeability, higher thermal insulation and lower thermal diffusion compared to ring spun yarn, due to their better integrity and higher packing density.

[20,21] Single jersey obtained from yarns produced at lower traveler weight has higher thermal resistance and lower water vapor permeability than that produced from normal or higher traveler weight. Air and water vapor permeability increases as twist factor increases, while thermal conductivity decreases.[20]

Thickness and stiffness depends upon the yarn of the knitted fabric while inlay yarn produces compression. Higher compression is obtained mainly by coarser elastic in inlay yarn.[5] Socks should give more comfort than other garments as there is less air circulation in socks and in shoes than garments or other parts of the body.[26] Socks made from modified cotton perform the highest level of comfort for diabetics.[24] Fibers and yarn properties influence thermal comfort and not the thickness of sock.[6] Relative influence of fabric mass, yarn count, stitch length, percentage cotton and fabric thickness on thermal comfort are 17%, 15%, 38%, 29% and 1% respectively.[2]

Diabetes and its chronic complications are a major public health problem and are growing quickly in the world.[4] Diabetes is a problem affecting millions of people all over the world. Private care must be done for feet diabetics by using occasion shoes and socks in order to avoid friction, sweating and high temperatures.[15] Diabetic socks must attain higher thermal comfort. This is obtained by a comfortable fit, no pressure points, no seams on fingers or uncomfortable seams, without lumps and constricting cuffs, suitable pressure and optimal dimensions; it should also avoid high temperature, bad respiration, exceeding temperature and sudation and suitable pressure value at the top part. This can be achieved by choosing high quality fibers, yarns and optimal fabric construction.[22] Diabetic socks have to be classified as spring-summer and autumn-winter; this will prevent incorrect use of these socks. Additionally, these socks have to be anti-bacterial and treated for 30 washings, and not to fit more than three shoe sizes.[22]

Lesser researches are published in the literature concerning the construction and specifications of diabetic socks. The aim of this study is to determine the general construction and quality levels of commercial diabetic socks, with approximately the same price as sold in the market.

2. Material and Method

The properties of seven single jersey diabetic socks selected from the commercial market were determined. The fiber combinations of the different socks and their chemical treatments as stated by the manufacturer are shown in Table 1.

From Table 1, it can be deduced that six of the seven socks contain cellulosic fibers (cotton, bamboo), including 5 containing more than 85% cellulosic fiber. Four samples contain polyester fibers with more than 60% for two samples and less than 11% for the other two samples. As known, the polyester fibers are not recommended for medical textile products, so the samples with more than 60% polyester can be considered as unhealthy products. The percentage of Lycra for the four socks range from 1% to 6% and one attains 30%. The 30% Lycra in sample 3 was surprising since this is the percentage applied in the production of Varicose Veins medical socks. This increases the pressure on the veins. Such socks can be used for pregnant diabetic patients and long-standing patients; therefore, it has to be mentioned on the label. Two socks are produced without Lycra, this can decrease their durability. Three socks are stated that they are microbe and/or odor resistant. The price of the tested socks ranges from 3.7 to 8 dollars.

The diabetic socks selected from the commercial market are tested for physical and mechanical properties, while the fiber combinations and chemical treatment were not determined and stated as mentioned by the manufacturers.

Table 2 demonstrates the standard methods applied for determining the fabric properties. The stitch lengths in the foot and leg areas were obtained by measuring the length of one hundred and twenty stitches. The yarn count and yarn type for foot and leg areas were determined by taking ten meters of yarns from both foot and leg areas.

Statistical methods, test of hypothesis, were applied for comparing and analyzing the obtained results.

Table 1. Percent Fiber Combination for different Socks

	Material Percent					
Number	**Cotton**	**Bamboo**	**Polyester**	**Nylon**	**Lycra**	**Country**
Sock1*	94				6	USA
Sock2	93			6	1	Not available
Sock3	8		62		30	Taiwan
Sock4	90		7		3	Pakistan
Sock5	90		9		1	USA
Sock6**		85		11	4	USA
Sock7**			89	10	1	USA

* Anti-Bacterial, Reducing Oder ** Odor-Resistance

Table 2. Standard methods applied for determining the fabric properties

Property	Stitch Density	Thickness	weight	Air Permeability	Bursting Strength	Abrasion Resistance	Thermal Resistance	Water-Vapor
Unit of measurement	per inch	mm	gm/m²	cm³/cm².sec	Kgf/cm²	cycles	mk.m².w⁻¹	%
Equipment	Magnifying glass	Teclock Corporation	Petit Balance (Chyo)	(JIKA) Toyoseiki	(JIKA) Toyoseiki	Martindale	Permetest	Permetest
Standard	ASTM					EN	ISO	ISO
Number	3887	1777	3776	737	3786	13770	11092	11092
Sample Size	Five samples were taken for every property for both foot and leg areas							

Table 3. Yarn construction of the tested socks

No.	Position	Yarn Type		No. of Yarns	Ne.	Equivalent Ne.
1	Foot	Single Yarn	Single Cover Lycra	2	20.2	19.5
	Leg	Three Doubled Yarns	Double Cover Lycra	4	18.8	
2	Foot	Three Doubled Yarns	Single Cover Lycra	4	17	16.4
	Leg	Four Doubled Yarns	Double Cover Lycra	5	15.9	
3	Foot	Three Doubled Yarns	Single Cover Lycra	4	20.8	20
	Leg	Three Doubled Yarns	Double Cover Lycra	4	19.2	
4	Foot	Single Cover Lycra	Single Cover Lycra	2	16	15.2
	Leg	Three Doubled Yarns	Double Cover Lycra	4	14.4	
5	Foot	Single Yarn	Single Cover Lycra	2	16.9	16.1
	Leg	Single Yarn	Double Cover Lycra	2	15.3	
6	Foot	Two Doubled Yarns	Single Cover Lycra	3	21	20.3
	Leg	Four Doubled Yarns	Double Cover Lycra	5	19.6	
7	Foot	Single Yarn	Single Cover Lycra	2	20.3	19.6
	Leg	Two Doubled Yarns	Double Cover Lycra	3	19	

Ne. - English count system

3. Results and Discussion

The obtained results were statistically analyzed to evaluate the thermal and non-thermal properties of the socks under investigation. In addition, they were utilized to determine the proposed levels for these properties based on some descriptive and analytical statistics from which a global comparison of the tested socks can be obtained. They help to set the working conditions for the higher quality diabetic socks. The socks selected were produced from different percent of blended fibers (cellulose, nylon, polyester and Lycra) and three of them were treated against bacteria and odor (1, 6 and 7).

3.1 Yarn Construction

Table 3 represents the yarn construction of the tested socks. This table confirms that:

1- The foot and the leg of the socks are produced from yarns of different construction. The foot is produced from two yarns: one of them consists of a Single Yarn or Single Cover Lycra (SCL), while the other, in most cases, consists of two or three doubled yarns. As for the leg, Double Cover Lycra (DCL) is the first yarn, while the second one can be two, three or four doubled yarn.

2- The equivalent yarn counts producing the foot and the leg are significantly different and vary from 14.4 Ne to 21 Ne for all the tested socks. The difference in yarn count within one sock varies from 1.1 Ne to 1.6 Ne. In all cases, the yarn producing the foot is finer than that producing the leg.

3- Depending on the yarn count, the socks can be divided into two groups: the yarn counts of the first group vary from 14.4 Ne to 17 Ne, while the counts of the second group vary from 19 Ne to 21 Ne. Besides, the equivalent count of the first group is within 16 Ne and that of the second group attains a value of about 20 Ne. There is no significant difference in the count within every group.

3.2 Socks Construction

Table 4, demonstrates the descriptive statistics for the construction measures of the studied samples. From this table and from the obtained results, the following can be stated:

1- Amongst all the properties, the value of the foot is greater than that of the leg with an exception for the stitch length for yarns without Lycra.

2- The coefficient of variation percent for the mass is greater in case of the foot measurement, which exhibits a difference of about 15% between the mean and the median of the samples due to a greater variability between samples. The mass percentage ratio between the foot and the leg varies from 3% to 41% depending on the raw material. The socks produced from bamboo demonstrate the higher values 41%, polyester product attain a value of 21.5%, while the cotton socks confirm a range from 3% to 35%. This range is attained at the cotton socks due to the fact that they are produced from a combination of different materials, which will oblige the producer to increase the mass of the foot to confirm the needed properties. The overall mean ratio is about 1.22.

3- The number of wales per inch is always greater in foot than in the leg by about one to three wales per inch; this is obtained through changing the stitch length. The results are more homogenous with lesser coefficient of variation and lesser difference between mean and median. The ratio is 1.08, which is within the standard; this is due to the fact that the wales per inch depend essentially on the machine gauge.

4- The number of courses per inch is always greater in the foot then in the leg. The difference between these two range from eleven to twenty courses per inch. The higher difference is obtained in the socks produced from polyester, followed by those from bamboo and then finally, cotton. This is due to the increasing feeding length and the ratio tends to about 2.88. The coefficient of variation is acceptable and a lesser difference between mean and median is obtained.

5- The ranges of both wales and courses depend on machine gauge, yarn count, yarn type, fiber varieties, feeding length and yarn tension. These factors have to be adjusted to attain the required properties with minimum production cost.

6- The density of the sock (Wales x Courses) demonstrate the same tendency of the course per inch.

7- The mean cover yarn stitch length in foot is about 3.33 of the leg. The percentage difference between the mean and the median is about 5% for foot, leg and the ratio between them. Moreover, the coefficients of variations are the same for both foot and leg.

8- The mean yarn stitch length in the foot is lesser than that in the leg and the ratio between them is 0.79. The mean and median differ in the same manner as cover yarn. However, the coefficient of variations differs significantly between the foot and the leg. This indicates different tendencies between the producers concerning the stitch length in the foot and the stitch length in the leg.

9- The ratio between the mean values of the tested properties of foot and leg for every sock separately are shown in Figure 1. From this figure, it is clearly seen that the variability within the mass of the fabric, wales/inch and Lycra stitch length are at minimum vales and have more or less the same trends. Only the yarn stitch length does not follow the same trend due to the difference in construction and count.

10- Table 5 represents the similarity of groups (non-significant) within the selected socks for the fabric construction for both values and ratios based on the Analysis of Variance. From the obtained results, it can be confirmed that the wales per inch are divided into three groups, 20–21, 17 and 16 for the foot and 19, 16 and 14 for the leg. The wales ratio between the foot and the leg for all socks are non-significant.

11- Three socks are similar in courses per inch in the foot and the leg sock. In case of the foot, the socks contain a high portion of cotton. However, in case of the leg, the socks contain polyester fibers. This can be due to the variation in machine setting. The similarity in ratios is obtained at the same fiber combination.

12- Yarn stitch length gives a higher significance between the measured properties. Lycra stitch lengths demonstrate group non-significance in leg and the ratio between the foot and the leg. Comparing the mass of the socks, only non-significant groups are obtained in the ratio values.

Table 4. Studied Socks Construction Measures

Status	Foot				Leg				F/H Ratio			
Property	Mean	Median	CV%	% R	Mean	Median	CV%	% R	Mean	Median	CV%	% R
Mass gm/m²	439.3	495.33	21.86	56.7	359.5	369.29	18.4	56.46	1.22	1.209	10.02	31.63
Wales per inch	18.89	19.8	11.17	34.42	17.52	18.60	12.44	33.67	1.08	1.084	4.726	17.38
Courses per inch	24.57	25.5	12.65	34.59	9.429	9.00	16.5	56.21	2.67	2.471	19.6	61.88
Density	469.8	517.4	22.68	67.05	165.1	160.00	20.73	78.73	2.88	2.671	19.74	74.9
SLL	5.483	5.2	11.63	34.65	1.67	1.76	11.69	32.93	3.33	3.17	17.57	41.8
SLY	11.19	12	18.56	45.59	14.24	14.5	8.65	24.57	0.79	0.828	19.88	56.93

SLL - Cover yarn stitch length in mm, SLY - Yarn stitch length in mm, %R - percentage range of the results

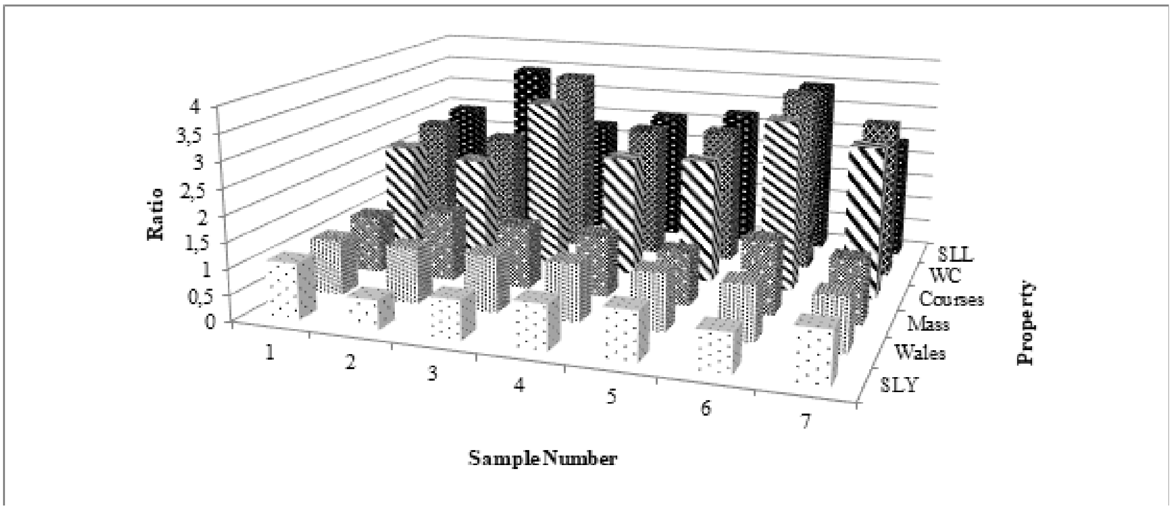

Figure 1. Ratio between the foot and leg construction properties for different socks

Table 5. Socks Construction Measures Similarity Groups

Comparison Sample		Wales per inch		Course per inch		SLL		SLY		Mass gm/m²	
		p-val	Sample	p-val	Sample	p-val	Sample	p-val	Sample	p-val	
Value	Value	1,3,6,7	0.292	2,4,5	0.185	5,7	0.867	1,6	0.762		
	Foot	2,5	0.528								
	Value	1,3,6,7	0.197	3.5.7	0.686			2,5	0.267		
	Leg	2,5	0.09					1,3	0.63		
								4,7	0.308		
Ratio	*Ratio*	All	0.134	1,2	0.06	3,6	0.544	1,3,7	0.08	1,5	0.199
	Foot / leg			3,6	0.619			2,6	0.903	2,6	0.278
				4,5	0.317			4,5	0.082	3,4,7	0.174

SLL - stitch length of Lycra in mm. SLY - stitch length of Yarn in mm. p-val - p value

Table 6. Socks Physical Mechanical Properties

Status	Foot				Leg				F/L Ratio			
Property	**Mean**	**Median**	**CV%**	**% R**	**Mean**	**Median**	**CV%**	**% R**	**Mean**	**Median**	**CV%**	**% R**
Bursting kgf/cm²	7.033	7	20.6	76.78	6.371	6.6	26.86	78.48	1.113	1.114	20.85	78.16
Abrasion cycles	1617	580	116.7	329.8	970.9	312	121.7	374.3	1.662	1.608	21.61	96.87
Thermal Resistance mk.m².w⁻¹	66.79	67.5	35.97	111.7	59.88	61.8	36.46	104.2	1.129	1.092	8.444	30.94
Evaporation %	27.17	28.7	21.43	72.87	34.2	34.3	14.9	47.08	0.79	0.821	13.41	41.65
Air Permeability cm³/cm².sec	80.79	56.92	62.1	177.6	183.9	202	31.99	98.61	0.459	0.306	57.29	164.6
Thickness mm	1.556	1.395	27.14	95.12	1.534	1.36	40.51	148	1.142	1.029	39.53	161.6

3.3 Socks Mechanical and Comfort Properties

Mechanical and comfort properties result of the socks demonstrate some difference between the foot and the leg as is detected in the construction properties. Table 6 represents the means value of some descriptive statistics obtained at foot, leg and the ratio between them. From this table the following can be detected:

1-The mean and median differ by about ten percent in the case of foot for all properties except the abrasion resistance, which demonstrates a difference of about hundred percent.

Eliminating the results of polyester socks, the difference is less than ten percent, since abrasion of polyester socks is about ten times higher than the mean of all other samples. This indicates that most of the cellulosic products are more or less identical.

2- Thermal properties, air permeability and thickness give a high deviation in both foot and leg status since they are affected by both material and yarn construction. This result is also confirmed by the values of the percentage range of the foot/leg ratio.

3- The ratios between the values of foot and leg for different socks properties are shown in Figure 2. From this figure, it can be clearly seen that the variability within air permeability and thickness attain higher values.

4- The foot to Leg ratio values for bursting, thermal and thickness are about 1.12; this indicates that the values in case of foot and leg are approximately equal, this is due to the fact that these properties depend essentially on the fabric structure and yarn structure. The thermal property indicates the minimum coefficient of variation.

5- The mean foot to leg ratio for abrasion resistance is about 1.66. This value is obtained due to a higher increase in the fabric density and the stitch length of the elastic yarn. This can be due to the producer's wish to decrease the cost, as the abrasion at the leg is not effective.

6- Air permeability and water evaporation percent exhibit an increase in the leg portion compared to the foot. This is due to the increase in courses and elastic yarn stitch length. The difference between the mean and the median is greater in case of air permeability compared to water evaporation since the first depends mostly on the fabric structure, while the other depends on both fabric structure and textile material affecting it.

7- Table 7 represents the physical and mechanical properties of non-significant groups, within the selected socks for foot and leg values, and the ratios between them based on the Analysis of Variance as well. From the obtained results, it can be confirmed that, for the tested socks the properties under investigation are divided into two or three groups with about four or five similar socks.

3.4 Proposed Requirements for Diabetic Socks

1- From the literature, the requirements of diabetic socks consist of:

a- On the diabetic labels, chemical treatments (anti-bacterial,

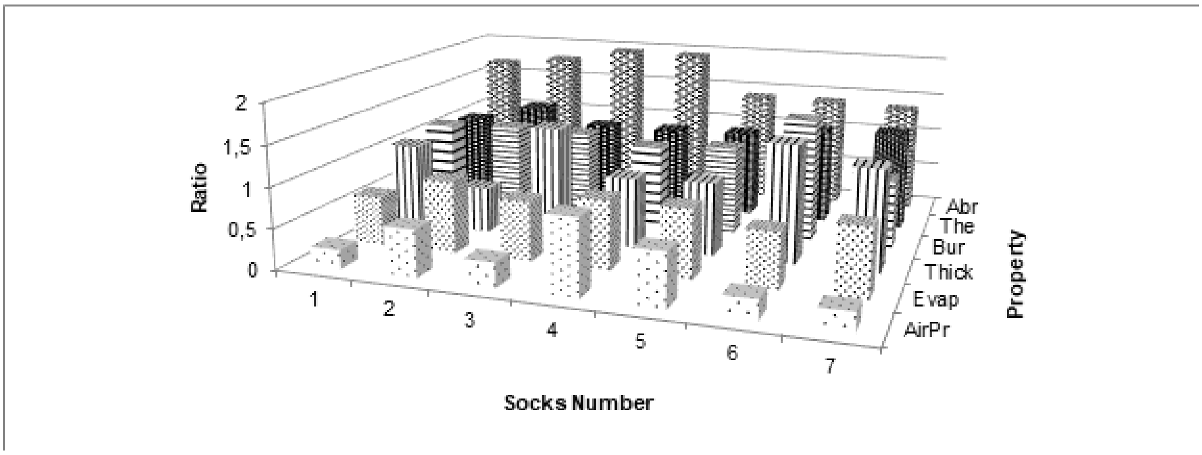

Figure 2. Ratio between the foot and leg construction properties for different socks

Table 7. Socks Physical Mechanical Measures Similarity Groups

Case	Bursting kgf/cm²		Abrasion cycles		Thermal Resistance mk.m².w⁻¹		Evaporation %		Air Permeability cm³/cm².sec		Thickness mm	
	Sample	p-val	Sample	p-val	Sample	p-val	Sample	p-val	Sample	p-val	Sample	p-val
Value	1,4,7	0.15	1,2,4	0.154	3,5	0.36	3.7	0.18	2,3,6,7	0.07	2,3,4,5,7	0.06
Foot	3,7	0.36	3,7	0.933	4,6	0.07	4,5	0.24				
Value	1,4	0.35	1,2	0.508	3,5	0.5	5,6,7	0.06	3,6	0.13	1,2	0.18
Leg	2,7	0.58	3,7	0.075	1,7	0.1	3,4	0.32	5,7	0.25		
	5,6	0.35										
Ratio	1,2,3,4,5	0.14	all	0.1	1,3,4,5	0.57	2,4,5,7	0.54	1,6,7	0.68	4,5	0.30
Foot/leg					2,6,7	0.97	3,6	0.07	2,5	0.35		

Table 8. Socks Physical Mechanical Measures Proposed Levels

Season	Position	Bursting	Abrasion	Thermal Resistance	Evaporation	Air Per.	Thickness
	Dimension	Kgf/cm²	Cycles	Tog=mk. m².W⁻¹	%	cm³/cm².sec	mm
Winter		Range	Range	Less than	Less than	Less than	More than
	Foot	7-8	430-500	65	22.5	65	2.25
	Leg	6.3-7.2	420-350	55	32.5	150	2.25
Summer				More than	More than	More than	Less than
	Foot	7-8	430-500	60	27.5	115	1.33
	Leg	6.3-7.2	420-350	50	34	230	1.33

Table 9. Global Measures of Comfort Properties

Season	Foot				Leg			
Measure	Winter		Summer		Winter		Summer	
Sample	Radar Area	Geometric Mean	Radar Area	Geometric Mean	Radar Area	Geometric Mean	Radar Area	Geometric Mean
1	1.732	**0.925**	0.725	0.548	1.629	**0.890**	1.065	0.716
2	1.475	**0.854**	0.941	0.682	2	**1**	0.633	0.548
3	1.302	0.804	1.519	**0.851**	0.893	0.636	1.878	**0.968**
4	0.913	0.649	1.916	**0.978**	1.484	0.859	1.565	**0.875**
5	0.848	0.617	2	**1**	1.097	0.727	1.980	**0.995**
6	1.738	**0.931**	0.956	0.681	1.271	0.778	1.650	**0.906**
7	1.128	0.737	1.470	0.833	0.910	0.657	1.996	**0.999**

anti-microbial or odor resistance) and the using period (winter or summer) had to be identified.

b- No definite request standards concerning the thermal properties or non-thermal properties is proposed for diabetic socks. The only requirement stated in the literature consists of attaining thermal comfort by maintaining proper temperature, respiration, sudation and pressure value at the leg.

2- From this study, the levels for thermal and non-thermal properties are proposed. These levels were determined based on the results obtained from the studied socks, taking into consideration the analysis of variance, similarity and ratio between mean and median. Table 8 demonstrates these levels.

3.5 Fabric Comfort

From the literature, the fabric comfort depends on air and vapor permeability, thermal transmittance and fabric thickness. Two global measures were proposed to evaluate the fabric comfort of the tested socks. They consist of the area of the radar graph and the relative geometrical mean for both summer and winter season. A summer sock has to attain a higher air permeability, vapor permeability, thermal transmittance and lower fabric thickness. However, winter sock need to perform lower air permeability, vapor permeability thermal transmittance and higher fabric thickness. Table 9 represents the value of global measures for the tested socks related to winter or summer periods. These values are obtained for both foot and leg areas. From Table 9, it can be deduced that the global value differs considerably when applied for winter or summer needs. Thus, the period of sock utilization has to be stated. The correlations between the radar area and the relative geometrical mean range from 0.993 to 0.998. It is better to apply the relative geometrical mean as global measure since the radar area is affected by the position of properties on the circle.

4. CONCLUSIONS

From the results obtained from the tested socks, the following can be stated:

1- The information on the labels of the tested socks consist only of the chemical treatments, the percentage of materials manufacturing the sock and their size.

2- Four materials are used in the formation of the tested socks. The percentage of these materials range from (8–94), (7–89), (6–11), (1–10) for cellulosic fibers (cotton or bamboo), polyester, nylon and Lycra respectively.

3- The foot yarn types of the tested socks consist mostly of single yarn, three doubled yarns and single covered Lycra. The numbers of yarns forming the foot range from two to four. While the leg yarn types consist mostly of three doubled yarns, four doubled yarns and double covered Lycra, the numbers of yarns forming the foot range from three to five.

4- For the tested socks, the count of the yarn forming the foot ranges from16 Ne to 20 Ne and that of the leg ranges from14 Ne to 19 Ne. Moreover, the yarn count forming the foot is always finer than that forming the leg for the sock.

5- The yarn and fabric construction of foot and leg areas are different, which tends to distinct levels in their properties. The foot region has higher values except for both percent evaporation and air permeability.

6- The proposed levels for the tested diabetic socks concerning winter and summer periods are obtained. These consist of:

a- Concerning the foot portion of winter diabetic socks, the values of thermal resistance, evaporation % and air permeability have to be less than (65 $mk.m^2.W^{-1}$, 22.5 percent and 65 $cm^3/cm^2.sec$) respectively; while for the leg portion, the values are less than (55 $mk.m^2.W^{-1}$, 32.5 percent and150 $cm^3/cm^2.sec$) respectively. Moreover, the thickness has to be more than 2.25 mm for both foot and top portions.

b- Concerning the foot portion of summer diabetic socks, the values of thermal resistance, evaporation % and air permeability have to be more than (60 $mk.m^2.W^{-1}$, 27.5 percent and 115 $cm^3/cm^2.sec$) respectively; while for the leg portion, the values are less than (50 $mk.m^2.W^{-1}$, 34 percent and230 $cm^3/cm^2.sec$) respectively. Moreover, the thickness has to be less than 2.25 mm for both foot and top portions.

7- A global measure for the thermal comfort properties based on the relative geometrical mean was proposed. From the results of the tested socks, two socks are available for winter (1, 2) and three for summer (3, 4, and 5).

8- The properties of the socks treated for odor-resistance are within the prescribed levels, but their global measures are less than 0.85, so they are not classified for any summer or winter period.

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