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Evaluation of Medical Socks Applied to Varicose Veins Therapy at Egyptian Market

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ABSTRACT

From the eighteenth century compression hosiery has been applied as therapeutic physical therapy. Mechanical compression procedures were mostly applied by wearing graduated compression hosiery as they tend to be convenient, economical, sustaining and ambulant therapeutic functions. Research and Development in the design of pressure hosiery not only increase their therapeutic abilities, but also improves consumer comfort. Engineering design for improving compression stockings was attained due to the progress in fibers, yarns and knitting processing.
On the Egyptian market different types of medical socket for Varicose Veins from different suppliers can be found. The evaluation of these socks were carried out based on the standard levels in the main time different non standard test was applied. The work will be carried on two parts. Firstly, the fabric construction of the sampled socks will be determined. Secondly the properties and performance will be evaluated. The first part will be presented at this paper. In this study seven imported, six local and four exports Egyptian medicals socks are sampled. The graduated pressure is obtained by varying both loop length and feeding tension. The fabric construction concerning fiber types, yarn types, stitch length, wales and course densities, mass and thickness for different socks were determined, at the points specified in the standards.
The local socks differ from that of other socks in all the fabric construction they contain polyester yarn, coarser yarns, higher stitch lengths and lesser wales per inch. The decrease of the number of wales from ankle to knee is significantly different between the three groups.
KEY WORDS: Varicose Veins, Compression Socks, Fabric Construction, Knitted Hosiery

1. INTRODUCTION

Since 400 years B.C. it has been denoted that for healing some cases it is possible to apply the compression techniques. Through Centuries it has been documented that it was applied as therapy for varicose veins and leg ulcers. The blood has to be driven back up the leg and then to the heart. The power needed for such return is provided by the contraction and relaxation of the calf muscle during walking.

The valves found in veins prevent the backflow of the blood. The efficiency of these valves determine the rate of venous blood return up the leg, the rate will be significantly slower when the valves are not competent [1]. If the rate of backflow blood pressure on the venous system decreases, further valve incompetence may occur this can increase the pressure in the veins, and can ultimately lead to a myriad of complications. Valve is considered damaged or collapsed when the valve cusps do not meet [2].

The Chronic venous insufficiency (CVI) is characterized by symptoms including: lipodermatosclerosis, hyperpigmentations, oedema, white atrophy and ulcers on the leg. In CVI, the calf muscle pump is not able to reduce venous pressure during walking, this increases pressure, commonly referred to as venous hypertension, ultimately leads to increasing capillary pressure [3].It is a serious condition which can be controlled by using compression hosiery also called Medical Elastic Compression Stockings (MECS). The severity of CVI is classified by the internationally accepted Clinical Etiology Anatomy Pathophysiology (CEAP) classification system. Patients who suffer from non-venous oedema may also benefit from MECS, as the compression exerted from the hosiery can reduce swelling. MECS can serve a wide group of people, since compression is one of the most important functions in the healing process [4].

The progress in both fiber and knitting technology introduce in the market high stretchable synthetic fibers, Polyurethane fiber (Spandex, Lycra, Elastane). Also single covered yarn, double covered yarn and core spun yarn were obtained from spinning technology, this consist of combining stretchable yarn with natural or synthetic yarn

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.Attachments were introduced at the knitting machines for obtaining body shape garments (stretchable clothes),in the mean time Computerizing of the Hosiery machine . By all these innovations an array of MECS with varying degrees of compression had been obtained [3]. Compression therapy can be used in addition to surgical treatment of varicose veins, sclera compression therapy and maintenance therapy in patients after a venous leg ulcer has healed [3], but the optimal levels of compression required to prevent relocation is not yet known [5]. Carrying case studies through clinical trials it has been proven that MECS can also reduce thromboembolic disease. The working mechanism of compression therapy, and thus MECS, is resultant from the pressure exerted on the leg. As an external application which applies compression to the skin in order to support the superficial venous system, this pressure forces a portion of the veins to narrow while the other portion completely closes. As a result, there is a reduction in the volume of blood in the veins, and the calf muscle pump can work better and the bloodstream is more easily able to move up toward the heart, and thus there is higher tissue oxygenation and better micro circulation [3].

Compression therapy regimen consist of two phase. Phase 1 is for the reduction of the oedema and / or healing of leg ulcers via non elastic bandages, while phase 2 tends to maintain the compression via MECS. The European Committee for Standardization (CEN) has distinguished four classes of graduated compression hosiery, which are based on the amount on pressure exerted at the ankle in mmHg.

The pressure decrease as it moves up from the ankle to the top of the thigh. The rates of decrease are mentioned in the CNE standards. MECS are formed from elastic thread or inlaid elastic and knitted elastic thread. The inlaid thread is fed at least every second course. They are obtained either on flat knitting machine or circular knitting machine. The hosiery obtained from flat knitted machine possesses more precise pressure and is more flexible but the sides are sewing together [3]. That produced at the circular knitting machine is always thinner than that obtained from the flat knitting machine, does not have a seam but the pressure is not as precise as in flat knitting stocking. The shape of this type of hosiery can be changed by changing the tightness of the courses and the tension of the knitted threads but doing this is quite difficult. Styles of compression hosiery consist of knee high, thigh high and full length [3]. It is not possible to suggest that one style is more effective than another style [2] MECS usually contains two types of yarns. High-strength yarns, ranging from 310dtex to 1,880 dtex, are inlaid and provide the necessary pressure and elasticity to be considered a medical product while finer elastic and non-elastic yarns form the weave. The inlaid yarns are also responsible for the comfort level of the hosiery, as that is the layer touching the skin. Together, these yarns generally consist of approximately 85% polyamide, 10% cotton, and 5% other materials such as multifilament fibers [4].

Properties other than pressure and pressure profile have to be carried out for MECS to determine their comfort and durability.

The performance of MECS in practice is the one which can enable the evaluation its ability. [5] Over a period of five years, the observation of 300 patients showed that compression hosiery did not significantly show a decrease in recurring venous ulcers. Also that the recurrence was more likely with patient who had more previous ulcers, poor ankle movement, lipodermasclerosis, and an ankle-brachial pressure index between 0.8 and 1.0 (as opposed to 1.0). In the time the higher grade MECS is more beneficial and more effective in regard to preventing the recurrence of venous ulcers, but it may result in noncompliance with patients.

Thermal comfort is defined as that condition of mind which expresses satisfaction with the thermal environment [6]. Therefore, there are no common set of environment or body temperatures that will satisfy everyone..

The Higher tightness fabrics shortened the spaces between each yarn, so avoided the air occupying in the fabric which was a burden to conduct heat and the heat conducts from one side to another side by the yarns. Whereas the lower tightness of the sample, there were air occupied in the fabric space which hindered the yarn to be a conductor to transfer heat.

The tensile strength of a material is the maximum amount of tensile stress that it can be subjected to before failure. [7] The hosiery will be put on and off daily by the user, the basic requirement of pressure hosiery is to maintain its dimensional stability and in turn keeping its function. Giving a constant and actuate pressure as stated is important to help relieving user's fatigue and swelling symptoms.

2. MATERIAL AND METHOD

Seventeen compression hosieries were taken from the Egyptian market. Seven of them are imported (I1 to I7), four were produced by one factory for export (E1 to E4), over demand are sold at the market, while the other six are produced from different factories in Egypt and sold at the local market (L1to L6). The hosieries are divided into, three classes A, four class I, nine classes II and one class III. Testing concerning, Yarn construction (material, count and type), Fabric construction (number of courses and wales, stitch length and weight), Physical and mechanical

properties (thickness, air permeability, extensibility and compression pressure), at all points mentioned at the compression standards, are determined under standard operating conditions. Statistical methods, test of hypothesis, were applied for comparing and analyzing the results.

3. RESULTS AND DISCUSSION

The analysis of hosieries under study tends to determine the yarn construction, fabric constructions and physical mechanical properties.

3.1Fiber Type

Table (1) represents the distribution of hosiery depending on their classes and material. From table it is clearly shown that most of the local hosiery are produced from polyester fibers, which does not seem to be adapted generally in medical textiles due to the conservation of static charge as polyester has low ability to decrease static charge since moisture absorption is only at a level of 0.4%.Three of the exported hosieries contain cotton fiber and they are classified into class I, II. Also the locally factories produce hosieries of A and I classes which are not efficient in preventing or treatment of venous leg ulcers.

Table (1) Distribution of hosieries by classes and material

Market	Import			Export			Local			
Number of Hosiery	4	1	2	1	2	1	1	2	2	1
% Cotton	-	-	-	17	17	-	-	-	-	-
% Nylon	70	60	55	58	58	70	-	-	-	65
% Polyurethane	30	40	45	25	25	30	40	35	30	35
% Polyester	-	-	-	-	-	-	60	65	70	-
Hosiery class	II	II	II	I	II	III	A	A,I	A,I	I

The blend percentage is constant; range is only 5%, in the exported hosieries since they are produced in only one factory. This is not the case for imported and local ones, range is about 15%, this is due to the fact that yarns are obtained from different factories, in which everyone has its production system.

3.2Yarn Structure

The percentage of different yarn structures and mean number of yarns per socks for the three groups are shown in table (2). Applying Chi-square test no significant difference in the yarn types that enter in the formation of the hosieries for the three groups was obtained. From t-test a significant difference with p-value of 0.001 and 2.0E-05 was obtained for the number of yarns forming the hosieries, between the local and both imported and exported ones respectively. From that the exported hosieries are obtained from three types of yarns with three feeders, the local hosieries are obtained by only two feeders and the imported hosieries are attained from four feeders.

Table (2) Types and number of yarns forming the hosieries under study

Origin	Imported		Exported		Local	
Yarn Type	number	percentage	number	percentage	number	percentage
Double Covered Yarn	12	41.379	8	50	6	46.154
Single Covered Yarn	2	6.897	4	25	2	15.385
Doubled Yarn	4	13.793	0	0	3	23.077
Single Yarn	11	37.931	4	25	2	15.385
Mean Yarns per Sock	4.143		4		2.167	
Standard Deviation	1.069		0		0.408	

Figure (1) demonstrates the percentage of counts in denier forming the studied hosieries

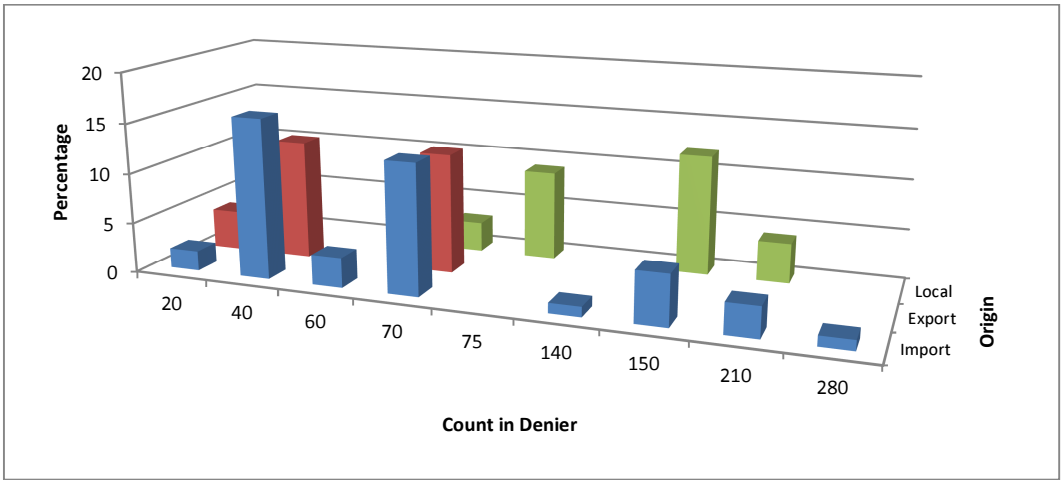

Figure (1) Count of different yarns in compression hosiery

The count of yarns that produce the exported hosieries ranges from 20to 70 denier. In case of imported hosieries the yarns count ranges from 20 to 280 denier with higher percentage lesser than 70 denier. Local hosieries are produced from coarser yarns from 70 to 210denier from which heavier and thicker hosieries can be expected.

3.3 Stitch Length

In compression hosiery both the yarn feeding length and yarn tension has to vary for obtaining the required pressure. The mean and standard deviation of stitch length at different positions for non elastic yarns are demonstrated at table (3a) and that of elastic yarns at table (3b). From table (3a, 3b) the stitch length increase considerably in case of imported and exported hosieries while this is not the case in local hosieries. In some cases the stitch length decreases, so the significance differences in stitch length for every group were determined through the paired comparison t-test, this is demonstrated in table (4). From table it can be deduced that the stitch length increase significantly in case of imported and exported socks for non elastic and elastic yarns, only for exported socks, between calf and knee low significant is shown at non elastic yarns and a significant decrease for elastic yarns. For local socks the significant increase is detected at elastic yarns only. From these results it can be deduced that the variation in pressure is based on the change in feeding length and tension at both yarn type in case of imported and exported socks, while this is carried out at elastic yarns for local socks.

Table (3a) Descriptive Statistics of stitch length for non elastic yarns at different points

Non Elastic Yarns								
Position	**ankle**		**shin**		**calf**		**knee**	
Statistics	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
Imported	2.645	0.432	2.774	0.435	3.001	0.56	3.055	0.586
Exported	2.818	0.099	3.05	0.12	3.245	0.097	3.633	0.354
Local	4.953	0.371	4.963	0.443	4.947	0.402	4.94	0.451

Table (3b) Descriptive Statistics of stitch length for elastic yarns at different points

Elastic Yarns								
Position	**ankle**		**shin**		**calf**		**knee**	
Statistics	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
Imported	0.52	0.086	0.667	0.137	0.787	0.134	0.9	0.218
Exported	0.553	0.045	0.695	0.039	0.855	0.068	0.788	0.078
Local	0.777	0.017	0.783	0.048	0.857	0.114	0.89	0.097

Table (4) Level of significance in stitch length for every group

Yarn Type	**non Elastic Yarns**			**Elastic Yarns**		
Tested Points	**ankle/shin**	**shin/calf**	**calf/knee**	**ankle/shin**	**shin/calf**	**calf/knee**
Imported	0.0020	0.0075	0.0200	0.0012	0.0127	0.0253
Exported	0.0067	0.0003	0.0812	0.0004	0.0012	0.0028
Local	0.3696	0.1550	0.4195	0.2829	0.0131	0.0112

The distribution of overall percentage increase in stitch length from knee to ankle for every group of hosiery is shown in table (5).In case of non elastic yarns, local hosiery attain a value of 2% only ,while in imported and exported hosieries the percentage increase varies from 4% to 42% depending on the class of the hosiery. In case of elastic yarns in the local socks the percentage of increase is much lesser than the other two groups. The imported hosiery attain a higher percentage increase than the exported one.

Table (5) Distribution of increase in stitch length by Material and Category

Non Elastic Yarn	**% Increase**	**-4to2**	**4to8**		**15to28**		**34to42**	
	Origin	**All Local**	**1Exp, 2Imp.**		**1Exp, 4Imp.**		**2Exp, 1Imp.**	
Elastic Yarn	% Increase	4to6	12to17	23to26	39to46	54to57	77to97	150
	Origin	Local			Export		Imported	

3.3 Wales per Inch

In knitting fabrics the wales per inch depends essentially on machine gauge, but in compressed hosiery due to tension applied on the yarns we can vary the value of number of wales this will affect the thickness, weight and pressure. The number of wales was determined for the socks under study. The values of wales per inch, for every group of socks at different positions, are shown in figures (2,3and 4).

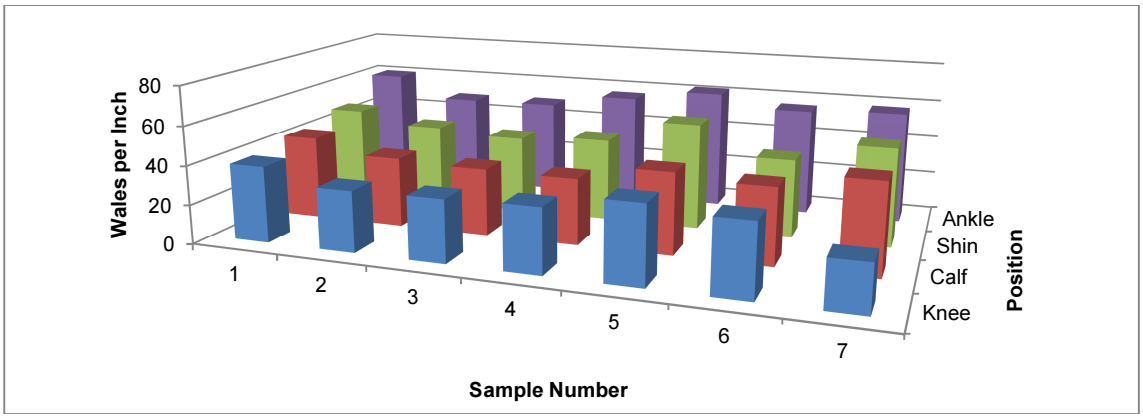

Figure (2) Number of Wales per Inch for Imported Socks at Different Positions

From these figures it is shown that there is a decrease in the wales per inch for all the socks but the rate of such decrease from the ankle to the knee is not the same. In imported hosieries the percentage decrease varies from 35% to59% ,Exported one has a decrease of 28% for socks containing cotton yarn and 33%for the nylon socks and the local yarns shows a percent decrease ranging from 6% to 16%. The constant decrease in local socks is due to the fact that they are obtained from the same factory only, while in other cases they are from different producers. Also the wales per inch at the ankle vary considerably from one group to the other, it is from 50 to 62 in exported 44 for cotton and 57 for nylon in exported and only 32 for local. These results will affect the performance of the compression hosiery, so it is difficult to determine the procedure that can be applied for obtaining an effective compressive hosiery. Determining the properties and performance of the studied socks can enable to attain the best operating conditions to these types of socks.

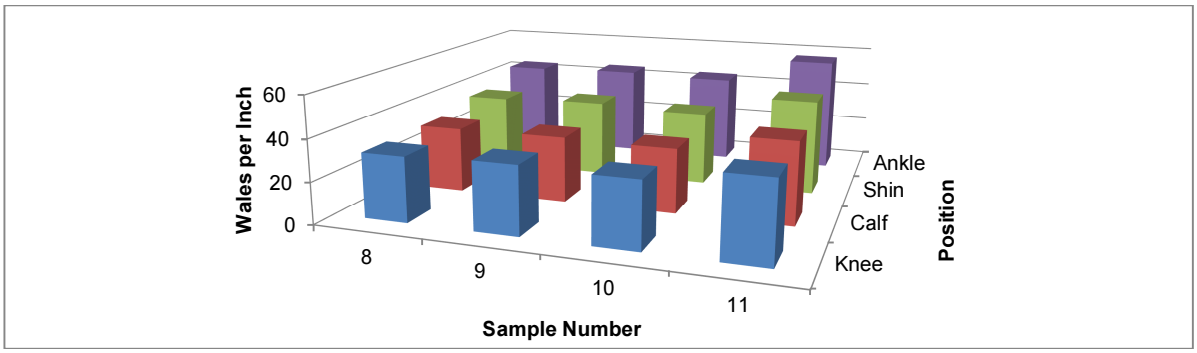

Figure (3) Number of Wales per Inch for Exported Socks at Different Positions

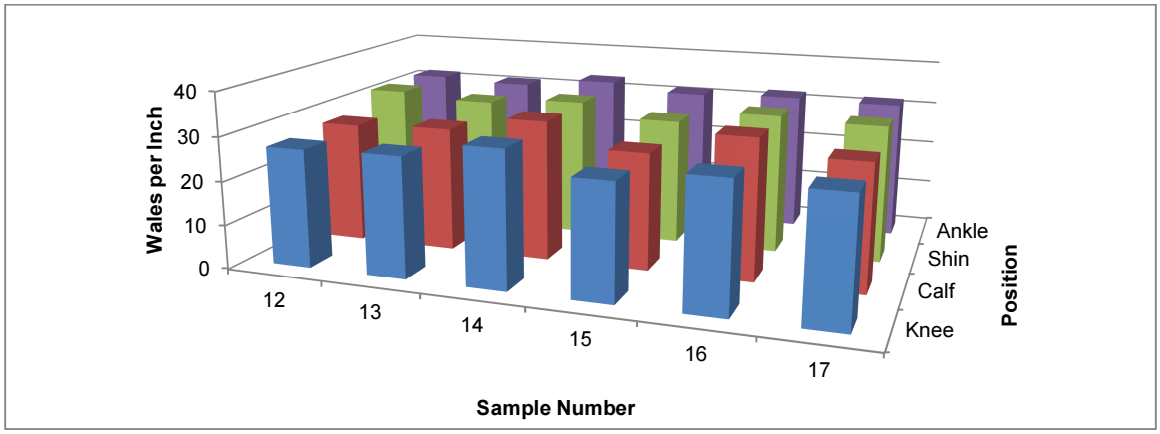

Figure (4) Number of Wales per Inch for Local Socks at Different Positions

3.3 Courses per Inch

In knitting fabrics the courses per inch depends essentially on feeding length, yarn tension and fabric take up tension. The values of courses per inch, for every group of socks at different positions, are shown in figures (5,6and 7). From these figures it is shown that the rate of variation in the courses per inch from the ankle to the knee is not the same for the different socks groups. In case of imported hosieries three of them have positive rate, with a percentage of 1% to 21%, while the other four demonstrate a percentage decrease ranging from 11% to 26%. All the exported hosieries demonstrate a negative rate with values from 1% to 19%. The local socks show an increase in rate of values from 3%to 12% and one sock has the same value of courses per inch for all points. The courses per inch at the ankle vary considerably between the socks under study. This depends essentially on feeding length and partially on fabric take up tension. The number of courses per inch at the ankle varies from 36 to 64 for imported, 48 for cotton and 56 for nylon in case of exported and 22 to 29 for the five of the local and 47 for the last one. The determination of best operating conditions for compression hosieries by carrying experiments based on their performance.

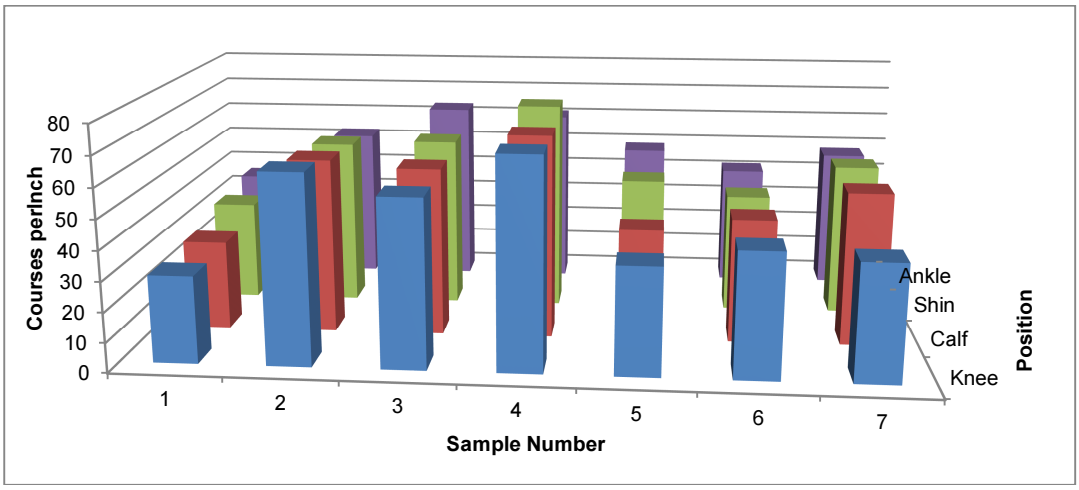

Figure (5) Number of Courses per Inch for Imported Socks at Different Positions

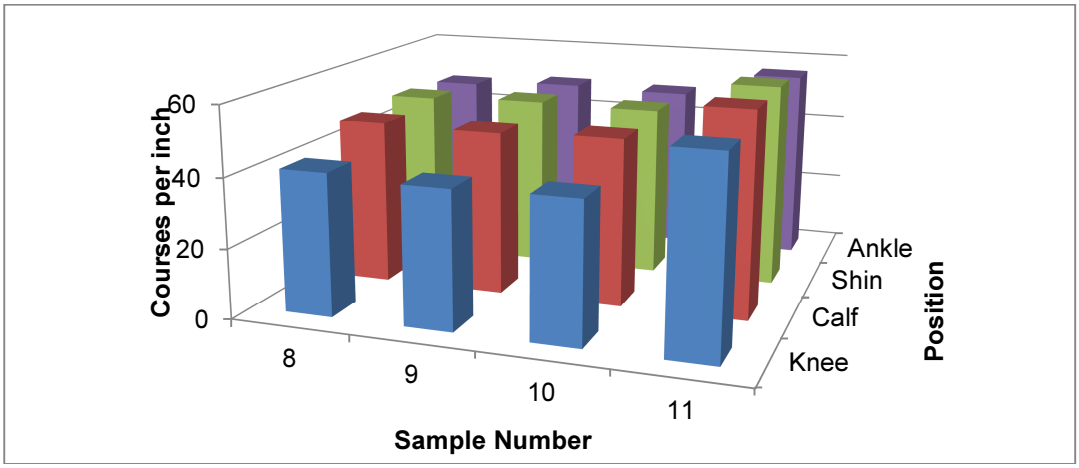

Figure (6) Number of Courses per Inch for Exported Socks at Different Positions

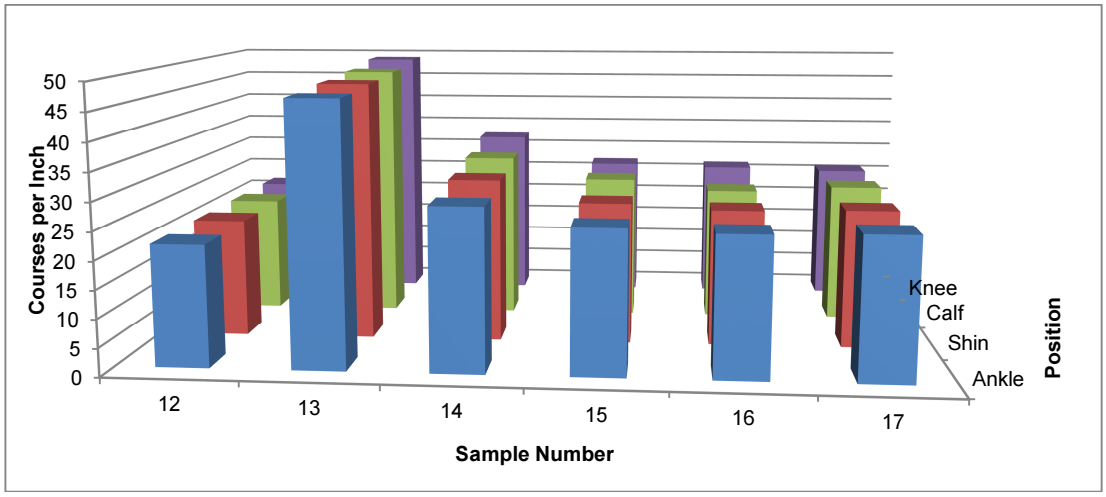

Figure (7) Number of Courses per Inch for Local Socks at Different Positions

3.4 Fabric Mass per Square Meter

The Mean mass per meter square of different hosieries at different positions are determined, this reflect all the construction parameters of the socks. When applying the analysis of variance, the mass of the fabrics, at the ankle, for the studied hosiery can be divided into four distinguished groups. Table (6) represents the distribution of hosieries by mass and categories in these groups. These results are similar to that obtained in case of wales per inch and courses per inch in the manner that the values are always divided into three groups each representing a category of the hosieries. Also in all socks the mass of the fabrics decrease from the ankle to the knee, its range is from 2% to 24% for imported hosiery and from, 0.5% to 5% in case of exported and 0% to 8% for local hosiery.

Table (6) Distribution of the hosieries by mass and category

Mass in Gram	220-230	300-330	330-350	360-390
Category	Imported (2socks)	Imported (5socks)	Exported	Local

3.4 Fabric Socks Thickness

Table (7) represents the distribution of hosieries based on the thickness in millimeter at the ankle. The thicknesses of the socks increase from 0.1% to 10.5% in case of the imported hosieries and from 1.2%to 2.9% for the exported hosieries, while it decreases from 0.1% to 7.1% for the local ones. This is the same tendency obtained for hosieries constructive factors.

Table (7) Distribution of the hosieries by thickness and category

Thickness in millimeter	0.5-0.6	0.76-0.84	1.05-1.	1.22-1.28
Category	Imported (2socks)	Imported (4socks) and all Exported	Local (2socks)	Local (4socks)

The correlation coefficient between wales per inch, courses per inch, mass and thickness of the fabric were obtained for all hosieries. Table (8) represents the hosieries' correlation coefficients which are higher than 0.6; from this table only the correlation between mass per square meter and the number of wales per inch has the same tendency in all the hosieries. Five of seven of the imported hosieries are demonstrated in this table and only one local sock, but no one of the exported socks is reflected in this table. It is interested to note that the fabric mass decrease as the number of wales increase. This is not the normal relation between fabric mass and the number of wales, but it can be due to value of tension applied on working yarns. No general tendency can be detected for other correlation coefficient.

Table (8) Correlation coefficients between fabric construction parameters of some hosiery

Sample Number	1	2	3	5	7	15
Mass/Wales	-0.88	-0.98	-0.94	-1	-0.89	-0.93
Mass/Courses	-0.96	*0.992*	-0.88	-1	-0.99	*0.881*
Mass/Thickness	-1	-0.96	-0.64	-0.96	*0.981*	*0.908*
Wales/Courses	0.95	*-0.99*	0.984	0.998	0.825	*-0.97*
Wales/Thickness	0.904	0.975	0.616	0.947	*-0.96*	*-0.78*
Courses/Thickness	0.96	*-0.94*	0.674	0.965	*-0.95*	0.811

Table (9) demonstrates the correlation coefficients for the exported socks. From table the correlation between mass and wales per inch is positive as it expected and is the only highly significant. The other correlations show the same tendency for socks containing cotton yarns. In case of local socks the correlation between mass and wales per inch is negative as in case of imported socks.

Table (9) Correlation Coefficients for the exported socks

Sample Number	8	9	10	11
Mass/Wales	0.837	0.91	0.909	0.882
Mass/Courses	*0.1*	*0.36*	*0.26*	-0.54
Mass/Thickness	*0.39*	0.551	*0.38*	0.538
Wales/Courses	*0.48*	0.59	*0.47*	*-0.16*
Wales/Thickness	0.822	0.821	0.586	0.865
Courses/Thickness	0.82	0.902	0.99	*0.19*

The results obtained for different socks fabric construction indicate that we can attain different operating conditions which can give efficient compression hosiery. This can be better determined after the determination of properties of the hosieries under study, which will be presented latter.

4 Conclusions

The fabric constructions of seventeen socks for venous disease taken from the Egyptian market were determined. They consist of three categories imported, exported and local their results are as follows.

- In imported hosieries the fibers that enter in the yarn formation consist of nylon and polyurethane, in case of exported socks cotton yarn is included, while for local ones polyester yarn is detected which is not recommended for medical purpose due to their highly generation of static charge.
- The number of yarns for fabric formation consist of two for local socks, three for exported and four for imported.
- The yarn count is significantly high in local socks than the other two categories.
- The stitch length at the local socks is highly significant than the other groups due to the coarser yarns.
- The stitch length of elastic yarns are highly significant between the ankle, shin ,calf and knee for the three categories in case of elastic yarns and only at the imported and exported socks for the non elastic yarns.
- The wales per inch decrease between ankle to knee with a value ranging from 35% to 55% for imported, 30% for exported and a range of 6% to 16% for local socks. Also the number of wales per inch is lower by about 40% than the other two categories.
- The rate of variation in courses per inch from ankle to knee differs between and within the socks groups.
- The mass and thickness of the local socks are significantly higher than the others socks.

- The correlation coefficients between wales per inch, courses per inch, mass and thickness are more significant in case of exported group than both exported and local.
- Determining the best operating conditions for obtaining efficient compression hosiery has to be based on physical properties and performance of the socks, this will be carried later.

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