Hand and Preference of Stretch fabrics for Fall and Winter Sportswear

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Abstract

This paper discussed the hand and preference of stretch fabrics for sportswear through subjective and objective hand evaluations. Twenty-two varieties of stretch fabrics for fall/winter sportswear fabrics were used. Seven main factors were classified through subjective evaluation and total cumulative variance value is 68.28%. According to correlations between objective hand and preference, there're different preferences for pants and shirts and in responding to preference for shirts, they do not put weights on gender. Correlations between subjective hand and preference shows that there is a similar tendency in preferences for pants and shirts regardless of gender.

Keywords: Sportswear; Stretch fabrics; Objective hand, Subjective hand, KES-FB

1. Introduction

People recognize the importance of health and enjoy sports as a fashion. As the types of sports are diversified and specified as one of important parts of our life, the concept on sportswear changes to what anyone can purchase and enjoy everyday rather than expensive clothing for athletes or someone [1].

Spandex fabric among various functional materials for sportswear was introduced about 50 years ago and has became the most useful material [2]. As production of stretch fabric increases every year, some quantitative studies are conducted about the mechanical properties but still need more improvements, in particular about the hand of stretch fabric.

The hand of fabric can be evaluated in terms of mechanical property and surface property as well as quality and preference including sensible functions through tactile and visible sensation. Thus, other than mechanical properties of stretch fabric, a study about subjective hand and preference should be conducted together. However, since there are few studies about the hand and preference of stretch fabric for sportswear, this study clarifies relationships among the subjective hand, objective hand and preference after collecting and sorting 22 kinds of men and women's stretch fabrics in order to understand the hand and preference of stretch fabrics for sportswear. This study also developed constituent factors and evaluation criteria of the hand and preference of stretch fabrics for sportswear so that it can contribute to improve quality of stretch fabric and diversify clothing materials.

2. Materials and Methods

2.1 Specimen

The specimen used for the study includes 22 varieties of stretch fabrics for fall/winter sportswear from JI HYUN Co., Ltd. The characteristics of the specimen are shown at Table 1.

2.2 Subjective Hand Evaluation

Through the 1st preliminary analysis, 9 out of 22 varieties of fabrics were suggested in certain size (30*30) for 30 experts to touch freely and describe them freely. Then, 170 adjectives were collected from their expressions. Among the 170 adjectives, 34 adjectives were selected to make up the 2nd preliminary questionnaires. With 15 out of 22 specimens, the 2nd preliminary research was conducted for 30 experts to evaluate 34 questions of adjectives in a 7-point scale. In the research, 60 experts and 60 non-experts freely touched 22 kinds of fabric specimens in holistic and then evaluated feeling of the fabrics in 31 questions of adjectives in a 7-point scale as well as conducted the subjective evaluation about comprehensive tactile sensation, preference for men's shirts/pants and for women's shirts/pants in a 9-point scale. The expert group was all women in 20's and 30's including graduate students, instructors, designers and MDs related to clothing and textiles, while the non-expert group was women in 20's and 30's of all kinds of careers.

2.3 Evaluation of Mechanical Properties and Objective Hand Evaluation

Measurement of mechanical properties includes 17 items of 6 factors including Tensile Properties, Bending Properties, Shear Properties, Surface Properties, Compression Properties, Thickness, and Weight under standard environment with the KES-FB system

2.4 Information Analysis

Factor analysis and correlation analysis of Pearson SPSS 12.0 were used for statistical

Table 1 Specification of sample used for the experiment

Sample No.	Fiber Contents (%)				Woven Structure	Fabric counts (ends*picks/5cm)	Weight (g/m^2)	Thickness (mm)	Usage suggested by Mfg	
	NYLON	PET	Airclo (PET)	PU						
A	57.0			23.0	Double	144*104	303.80	0.840	Men	Shirts
B	20.0				Cloth	136*137	309.25	0.883		
C	37.0			46.0	Twill	134*142	298.78	0.710		
D	17.0				Double	136*130	236.83	0.670		
E	42.0			43.0	Cloth	88*96	321.13	0.650		Pants
F	15.0				Twill	104*72	363.13	0.937		
G	35.0			50.0	Plain	104*84	278.90	0.443		
H	15.0				Twill	130*94	234.18	0.347		
I		35.0		58.0	Twill	58*142	180.08	0.397		
J	5.0				Twill	104*108	331.40	0.633	Women	Shirts
K		33.0		61.0	Double	86*144	127.75	0.249		
L	6.0				Cloth	92*96	116.43	0.197		
M	94.3				Double	172*102	155.78	0.252		
N	5.7				Cloth	104*87	122.45	0.367		
O	93.3				Twill	168*120	156.85	0.326		
P	6.7				Twill	160*136	176.48	0.319		
Q	89.0				Twill	177*144	167.13	0.286		
R	11.0				Plain	112*71	187.85	0.298		Pants
S	95.9				Double	124*124	255.58	0.500		
T	4.1				Cloth	162*148	197.35	0.553		
U	88.0				Twill	110*104	236.08	0.420		
V	12.0				Twill	112*110	291.75	0.660		
	93.8				Twill					
	6.2				Double					
	95.4				Cloth					
	4.6				Double					
	92.7				Cloth					
	7.3				Twill					
	88.2				Double					
	11.8				Cloth					
		87.2								
	12.8									
	87.4									
	12.6									
	97.2									
	2.8									
	94.3									
	5.7									
		89.3								
	10.7									
		93.0								
	7.0									
		94.6								
	5.4									

3. Results

3.1 Subjective Hand Evaluation by Factor analysis

Table 2 shows factor analysis results of 31 adjectives for the subjective evaluation. If the Eigen value is more than 1, the value was selected with the varimax rotation. Among the total 7 factors, the first factor was named a ‘bulky/thermal character’ as related to volume of the surface and thermal feeling like cold or warm, while the second factor named ‘surface property’ as reflecting the surface status of fabrics. The third factor, ‘stiffness’ is about if fabric is stiff and straight. And, the fourth factor, ‘drapability’ consists of adjectives like ‘drapable’ or

'saggy' of fabrics. The fifth factor was named 'extensibility' since it was related to elasticity of specimen or compression elasticity of surface; the sixth factor named 'sticky' for the degree of sticky clinging to a body; and finally, the seventh factor named 'moisture-related property' to show the degree of moisture of fabrics'. The total cumulative variance value was high about 68.283%.

3.2 Mechanical Properties

3.2.1 Tensile Property

The tensile property can be explained, when fabric is stretched with force in a certain direction, as a relationship between the force and tensile strain and between the force and tensile force. [3] EM expresses extensional strain on the tensile load of 500gf/cm. In the experiment, EM measurements of the 22 specimen range between 8.41 and 32.00, which prove that the fabrics stretch better than other general fabrics. The LT ranged from 0.39 to 0.82 with less stiffness compared to other fabrics. The range of WT is between 35.68 and 55.30 as much larger values that reflects better extendibility than other fabrics. It may be because that most specimens of the experiment use the spandex thread with a high percentage of elongation on the warp and weft parts. Meanwhile, RT ranges between 28.24 and 64.67.

All specimens except one showed values more than 50.00, which means RT has the same tendency with WT values. Since RT values are high, it is expected that the stretch fabric recovery better and has higher dimensional stability compared to other fabrics.

3.2.2 Bending Property

The bending property is related to drapability, tactile sensation, and wrinkles, explained with B and 2HB. The B ranged from 0.038 to 0,259, which were relatively high values. It means that the stretch fabric cannot be easily bended and has a strong resistance. Meanwhile, the 2HB was measured between -0.051 to 0.228. It indicates that the stretch fabric is appropriate to form silhouette of a voluminous box style that keeps space from a body, although it is not well recover from bending. In other words, it would be advantageous that B and 2HB of the stretch fabric is used for spacious silhouette formation rather than for silhouette that emphasizes a body line compared to other fabrics.

Table 2. Results of factor analysis

Factor	Measurement*	Factor score	Eigen Value	Cumul.Pres.Variance
Bulky/Thermal character	Dadut-hada/Dadut-hazianta(warm/not warm)	.883	5.792	19.308
	Chagapda/Chagapzianta(cold/not cold)	-.845		
	Pokshin-hada/Pokshin-hazianta(compressible/incompressible)	.839		
	Shiwon-hada/Shiwon-hazianta(cool/not cool)	-.822		
	Gimoga-ita/Gimoga-upta(rasing/not rasing)	.793		
	Dookupda/Dookupzianta(thick/not thick)	.752		
	Moogupda/Moogupzianta(heavy/not heavy)	.680		
	Sagakkulinda/Sagak-kulizi-anunda(rustle/not rustle)	-.677		
	Toktok-hada/Toktok-hazianta(compact/not compact)	.603		
	Gauchilda/Gauchilzianta(rough/not rough)	.864	3.527	31.064
Surface property	Maekurubda/Maekurubzianta(smooth/not smooth)	-.837		
	Kasl-kasl-hada/Kasl-kasl-haziannta(scatchy/not scratchy)	.797		
	Otol-dotol- hada/Otol-dotol- hazianta(coarse/not coarse)	.740		
	Bududrubda/Bududrubzi-anta(soft/not soft)	-.704		
	Dandan-hada/Dandan-hazianta(hard/not hard)	.778	2.934	40.845
Stiffness	Kang-hada/Kang-hazianta(durable/not durable)	.714		
	Dakdak-hada/Dakdak-hazianta(Dakdak-hadzianta)	.694		
	Butbut-hada/Butbut-hazianta(stiff/not stiff)	.572		
	Chuginda/Chugizianunda(saggy/not saggy)	.768	2.597	49.503
Drapability	Drapesungiitda/Drapesungi-upda(drapable/not drapable)	.729		
	Uyeun-hada/Uyeun-hazianta(flexible/unflexible)	.694		
	Hanul-gaurinda/Hanul-gaurizi-annunda(flossy/not flossy)	.572		
	Shincuksungi-itda/Shincuksungi-upda(resillience/not	.880	2.445	57.653
Extensibility	resillience)	.874		
	Nulananda/Nulanazi-annunda(stretchy/not stretchy)	.863		
	Tanryukitda/Tanryuki-upda(elastic/not elastic)	-.837	1.938	64.114
Sticky	Dalabutnunda Dalabutzi-annunda(static/not static)	.812		
	Kunkun-hada/Kunkun-hazi-anta(sticky/not sticky)	.586		
	Gamkinda/Gamkizi-anta(clingy/not clingy)	-.725	1.251	68.283
Moisture related property	Chokchok-hada/Chokchok-hazi-anda(wet/not wet)	.669		
	Kunjo-hada/Kunjo-hazi-anda(dry/not dry)			

3.2.3 Shear Property

The shear property is about formation by extended rotation with a certain angle on a side of a specimen after the other side is fixed with certain load. The shear property consisting of G and 2HG and 2HG5 affects combination with body lines, drapability and so on.[3] The shear rigidity ranged from 0.52 to 2.82. It shows that the stretch fabric can form voluminous silhouette but lacks drapability and recovery from bending. Meanwhile, the shear hysteresis was measured between 0.57 and 11.70 in large

values. It indicates that the stretch fabric has less recovery from bending and less drapability as shown in the shear property.

3.2.4 Surface Property

The surface property can be explained with MIU, MMD and SMD show smoothness and structural evenness of surface of the fabric. MIU ranged from 0.020 to 0.274 that are relatively similar to other fabrics. Union fabrics with warp and weft has less regularity of surface, while other fabrics except some [3] show similar surface evenness as they are all woven with threads of the same warp and weft. MMD also had similar values overall compared to other fabrics. Meanwhile, SMD was measured between 0.780 and 2.770 as the lowest values, which means that the stretch fabric gives not rough and smoothness compared to other fabrics.

3.2.5 Compression Property

The compression property, which is related to volume of fabrics, can be explained with LC, WC, and RC. The LC of all specimens had relatively similar values with other fabrics ranged between 0.130 and 0.323. It implies that the stretch fabric has less resistance to compression, so it can be compressed fast with minor force. It also has large surface volume. WC was measured from 0.030 to 0.406, larger than other fabrics. It indicates that the stretch fabric has higher thickness but can be compressed because of the elasticity of spandex thread. The range of RC values was between 38.14 and 76.67, while most of them were more than 50.00 as high RC values. This reflects the property of the stretch fabric in good recovery from compression compared to other fabrics.

3.3 Relationship between Objective Hand and Preference

Table 3 shows the result of correlation analysis between objective hand factors and preference and to measure the degree of correlation.

In case of the expert group, there was a negative correlation between holistic preference, and MMD and SMD among surface properties. It means that experts prefer the stretch fabric of which surface is smoother and has nice feeling, not rough. In the perspective of HV and holistic preference showed positive relations with Numeri (softness), which suggests that the stretch fabric with silky surface as well as softer and smoother feeling is preferred as there is less change of friction force occurring when touched by hands, as shown at the result of surface properties.

The preference for men's shirts among tensile properties had a negative correlation with LT, but a positive with WT. It implies that flexible rather than stiff, and well-stretching fabric is preferred. Also, the preference for men's shirts had negative correlations with all values of the bending property and the shear property. It means that the stretch fabric which is not stiff and has better recovery from bending, as well as fabric which has less resistance to shear strain, better recovery and drapability is preferred. Among compression properties, WC value had a negative correlation with the preference for men's shirt, which indicates that experts prefer the stretch fabric without surface volume. In addition, they also prefer lighter and thinner fabrics considering the usage for sportswear and in case of sweating. Also, the preference for men's shirts had negative correlations with Numeri (softness), Fukurami (fullness and softness), Sofutosa (soft feeling) and THV. This means that the, less silky, less extensible, less compressible, lighter fabrics are preferred for men's shirts. It shows a different tendency from the correlation with mechanical properties. Thus, it needs to be evaluated along with the subjective hand evaluation. Meanwhile, the negative correlation between preference and THV shows that there is a difference from sensitivity measured through the KES-FB system.

Preference for men's pants had positive correlations with EM and LT among tensile properties. It means that, unlike the preference for men's shirts, stiff fabrics with some rigidity are preferred. The preference also had positive correlations with all mechanical properties including bending and shear. For men's pants, stiffer fabrics that can keep shapes as well as fabrics with resistance to shear strain are preferred for shaping voluminous silhouette. It is almost opposite result from the preference for men's shirts, showing that mechanical properties are different for men's pants and shirts respectively. The negative correlation with MIU among surface properties shows preference of rugged fabrics for men's pants. Opposite from the preference for men's shirts, heavier and thicker fabrics are preferred. It's very interested that expectation of respondents between pants and shirts.are different Among compression properties, LC and RC had positive correlations wit the preference for men's pants. It indicates that fabrics with less surface volume and less recovery from compression are preferred. Among primary hand values, it had a positive correlation with Sofutosa (soft feeling), which is an opposite tendency compared to the fabric for men's shirts. For men's pants, preferred fabrics are soft, voluminous and silky, and flexible for bending. This is a little bit different from the above mechanical properties.

Preference for women's shirts had the same tendency with that for men's shirts in correlations with all mechanical properties including tensile, bending, shear, compression, thickness and weight. It seems that respondents do not consider gender in answering about the preference for shirts. In primary hand values, however there were a few differences that it had a negative correlation with Koshi (stiffness). It indicates that soft rather than stiff fabrics are preferred for women's shirts. In correlations with Fukurami (fullness & softness), Sofutosa (soft feeling) and THV, the tendency was similar to preference for men's shirt, which means that fabrics which are less silky, less extendible, less compressible and lighter are preferred. It also suggests that respondents consider the usage for shirts rather than gender.

Preference for women's pants had only three items with correlations which are LT, 2HB and SMD. It had a positive correlation with G among tensile properties. For women's pants, stiffer fabrics are preferred to keep shape in some degree. The positive correlation with LC represents preference of less drapable fabrics for women's pants. LC among compression properties also had a positive correlation like preference for men's pants, which means that fabrics with less surface volume are preferred. However, there were no correlation with all primary hand values, thickness and weight.

In the non-experts group, overall correlations were low compared to the expert group. There were no correlations with preferences for men's pants and women's pants. In the category of holistic preference, there were positive correlations with EM and SMD and a negative correlation with RT. In other words, non-experts overall prefer fabrics with surface unevenness and those that well stretch and keep shapes in certain degree. The non-experts preferred fabrics with surface unevenness, hard surface volume, and good compression with lesser force, like the expert group, for men's shirts, since the preference had a positive correlation with SMD, but a negative with LC.

In summary, in the category of holistic preference, experts

showed correlation with surface property only, while non-experts showed tensile and surface properties. However, they had the same tendency that thickness and weight give negative impacts on preference for women's shirts.

Overall, experts prefer less stiff, well-stretching, drapable, and lighter fabrics for shirts, and rigid fabric that can keep shapes well for pants. They also prefer fabrics with less compressible, less surface volume but with weight and volume.

In particular, among the items with high correlation coefficients, B and 2HB value among the bending property, and G, 2HG and 2HG5 among the shear property had high correlation with men's shirts and women's' shirts and pants. Also, the high correlation with WC among the compression property reflects properties of stretch fabrics for sportswear as one of mechanical properties.

3.4 Relationship between Subjective Hand and Preference

Table 4 shows results of correlation between preference and subjective hand. 'Bulky/thermal' showed negative correlations with all preferences for shirts and positive ones with all preferences for pants. In other words, people prefer lighter and cooler fabric for shirts and fabric with opposite properties for pants.

The 'surface property' has negative correlations with holistic preferences and preferences for shirts, while having a positive correlation with preference for men's pants. This implies that people prefer smoother fabrics for shirts and a little bit uneven fabrics for men's pants.

The 'rigidity' had a positive correlation with preference for pants, while having a negative correlation with that for shirts. It reveals that people stiffer and stronger fabric for pants rather than for shirts.

The 'drapability' had a positive correlation with preference for pants, but a negative correlation with that for men's pants. It indicates that more drapable fabric is preferred for shits and stiff fabric for men's pants. A positive correlation was appeared between the 'extendibility' and holistic preference for pants and for women's shirts. It emphasizes the importance of extendibility, which is one of the core properties of stretch fabrics for sportswear and affects the holistic preference.

Table 3. Correlation coefficients between objective hand and preference

		Experts					Non-experts		
		Holistic preference	Preference for men's shirts	Preference for men's pants	Preference for women's shirts	Preference for women's pants	Holistic preference	Preference for men's shirts	Preference for women's shirts
Tensile Property	EM	-	-	.099*	-	-	.081*	-	-
	LT	-	-.097*	.130**	-.088*	.092*	-	-	-
	WT	-	.145**	-	.085*	-	-	-	-
	RT	-	-	-	-	-	-.129**	-	-
Bending Property	B	-	-.174**	.191**	-.220*	-	-	-	-
	2HB	-	-.172**	.130**	-.224**	.094*	-	-	-
Shear Property	G	-	-.136**	.136**	-.214**	-	-	-	-
	2HG	-	-.205**	.118**	-.251**	-	-	-	-
	2HG5	-	-.136**	.086*	-.208**	-	-	-	-
Surface Property	MIU	-	-	-.081*	-	-	-	-	-
	MMD	-.146**	-	-	-	-	-	-	-
	SMD	-.132**	-	-	-	.092*	.094*	.084*	.103*
Compression Property	LC	-	-	.082*	-	-	-	-.097*	-
	WC	-	-.180**	-	-.192**	-	-	-	-
	RC	-	-	.095*	-	-	-	-	-
	T	-	-.199**	.098*	-.225**	-	-	-	-.083*
Thickness	W	--	-.278**	.211**	.331**	-	-	-	-.094*
Weight	KOSHI	-	-	-	-.114**	-	-	-	-
Objective hand	NUMERI	.086*	-.083*	-	-	-	-	-	-
	FUKURAM	-	-.200**	-	-.205**	-	-	-	-
	I	-	-.231**	.194**	-.218**	-	-	-	-
	SOFUTOSA	-	-.150**	-	-.137**	-	-	-	-
	THV								

**p<.05, **p<.01*

Table 4 Correlation coefficients between subjective hand and preference

	Bulky/Thermal character	Surface property	Stiffness	Drapability	Extensibility	Sticky	Moisture related property
Holistic hand preference	-	-.217**	-	-	.118**	-	-
Preference for men's shirts	-.172**	-.092*	-.170**	.173**	-	.138**	.092*
Preference for men's pants	.143**	.100*	.248**	-.121**	.148*	-	-
Preference for women's shirts	-.201**	-.147**	-.214**	.233**	.099*	.157**	.094*
Preference for women's pants	.088*	-	.147**	-	.173*	-	-

*$p<.05$, **$p<.01$

4. Conclusions and Implications

Clothing materials and quality improvement of stretch fabrics for sportswear by analyzing relevance among constituent factors

of the hand and preference of stretch fabrics for sportswear.

1. The factor analysis for subjective hand evaluation shows that the whole specimens are bound by 7 factors including 'bulky/thermal character', 'surface property', 'stiffness', 'drapability', 'extensibility', 'sticky', 'moisture-related property'. And holistic cumulative variance value is 68.283%, which is relatively high.
2. The spandex contained stretch fabrics tend to be less stiff, well stretching and recovering faster compared to non-spandex fabrics. However, in terms of the shear property, stretch fabric has less drapability and less recovery from wrinkling. The surface property is softer and smoother than other materials. On the compression property, stretch fabric can be compressed more than others and has larger surface volume. Also, its better recovery from compression reflects the own feature of stretch fabric different from general fabrics in general.
3. According to relationship between objective hand and preference, experts prefer less stiff, better stretching, drapable and lighter fabrics for shirts. For pants, however they prefer more rigid fabric that can keep shapes and not be good compressed with less surface volume, but with weight and volume. The bending property value and the shear property value have high correlation coefficients in preference for men's shirts and women's' pants and shirts. It means they are the mechanical properties that reflect well the unique features of stretch fabric for sportswear.
4. Correlation analysis between subjective hand and preference shows that there is a similar tendency in preferences for pants and shirts regardless of gender. For shirts, less voluminous, cool, soft and drapable fabric is preferred. Also, extendible, and dry fabric is preferred for shirts. Meanwhile, voluminous, warm and uneven, rigid and extendible fabric is preferred.

The study clarifies hand of stretch fabric for fall/winter sportswear as well as various factors affecting consumers' preference. Thus, it can contribute to being used as fundamental information to specify quality improvement and develop the broad range of usage. However, the limitations pf this study are limited to fall/winter stretch fabric, it would be troublesome to apply the same hand and preference to other various stretch knits for sportswear or fabric for other seasons. In addition, although the fabric hand and preference may have a special relationship with finishing or color, the study does not control the factors in researching mechanical properties and preference. Therefore, future studies may supplement such limitations of the study. If future studies broaden study subjects such as knitwear for T-shirts or stretch fabric and knitwear for ordinary wears other than stretch fabric for sportswear, the stretch fabric market could be more expanded.

Acknowledgements

The research was supported partially by "The Second Stage of BK 21"

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