(REFEREED RESEARCH)

DETERMINING THE EFFECTS OF DIFFERENT SEWING THREADS AND DIFFERENT WASHING TYPES ON FABRIC TENSILE AND SEWING STRENGTH PROPERTIES

FARKLI DİKİŞ İPLİKLERİ İLE FARKLI YIKAMA TİPLERİNİN KUMAŞ VE DİKİŞ MUKAVEMETLERİNE ETKİLERİNİN İNCELENMESİ

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ABSTRACT

In this study, the aimisto experimentally determine the effects of different sewing threads and different washing types on fabric tensile and sewing strength properties. In this context, two types of denim fabrics (one produced with elastane and the other without elastane) were selected as samples. Then, experimental samples were sewed with three different sewing threads (polyester/polyester core-spun, polyester/cotton core-spun and polyester filament) at the same thread number,and three different washing processes (rinse, enzyme, and stone with enzyme) were applied. Afterwards, fabric tensile and seam strength tests were performed by following the related standards. Finally, the test results were analyzed using a statisticalsoftware package programme (SPSS 20.0). It was seen that, in general the relationship between the washing type and fabric tensile strength was statistically significant.In addition, the highest sewing strength valueswere obtained before washing, and the lowest values were seen after stone washing with enzyme. The sewing thread giving the highest warp sewing strength values in all washing types was the polyester filament.

Keywords: Sewing, sewing strength, sewing thread, denim washing

ÖZET

Çalışma kapsamında, farklı dikiş ipliği ile farklı yıkama tiplerinin kumaş kopma ve dikiş mukavemeti üzerine etkilerinin deneysel olarak belirlenmesi hedeflenmiştir. Bu amaçla, biri elastanlı diğeri elastansız iki farklı denim kumaş numune olarak seçilmiştir. Ardından numuneler aynı numarada üç farklı dikiş ipliği (polyester/polyester core-spun, polyester/pamuk core-spun ve polyester filament) ile dikilmiş ve kumaşlara üç farklı yıkama prosesi (rins, enzim ve enzimli taş yıkama) uygulanmıştır. Daha sonra standartlara uygun olarak numunelerin kumaş kopma ve dikiş mukavemeti değerleri belirlenmiş ve sonuçlar SPSS 20.0 programı yardımıyla istatistiksel olarak analiz edilmiştir. Genel olarak yıkama türü ve kumaş kopma mukavemeti arasındaki ilişkinin istatistiksel olarak anlamlı olduğu görülmüştür. Ayrıca, en yüksek dikiş mukavemeti değerleri yıkama öncesinde görülürken en düşük değerler enzimli taş yıkama sonrası elde edilmiştir.Tüm yıkama türlerinde en yüksek çözgü dikiş mukavemeti değerlerini veren dikiş ipliği polyester filamentolmuştur.

Anahtar Kelimeler: Dikiş, dikiş mukavemeti, dikiş ipliği, denim yıkama

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1. Introduction

Denim fabrics are currently used in many fields to produce trousers, jackets, shirts, blouses, working clothes and bags; furthermore, its production and consumption has constantly increased. Today, people of all ages can havedenim garments. This is due to the comfort and durability of denim fabric and its ability to create diversity to satisfydifferent aesthetics and fashion sense. The purpose of some of the washing procedures applied to denim fabrics is to give variety to the denim.

A literature review reveals many studies on the denim washing process. In some of these studies, different performance properties after washing process of denim fabrics, including abrasion resistance, pilling, air

permeability, dimensional stability and stiffness, were examined. Karazincir and Duru Baykal investigated that the effects of different washing types on the selected denim fabric's strength and elongation properties. It was obtained from their study that rinse washing process did not have significant effect on the strength and elongation values but enzym and enzymatic stone washing processes decreased fabric elongation in both warp and weft directions (1).The study of Khedher et al. showed that, in the case of washed denim fabric, it was advisable to avoid the line of succession of treatments containing the resin-treatment and mixed washing process (2). Çetinaslan et al. revealed that when the increase in fabric weights, the loss ratio of tensile and tear strength was decreased. The strength values of denim fabrics were decreased after washing process (3). Aslan indicated that different denim fabric types may exhibit different performances in terms of parameters such as size, density, color and weight changes, colorfastness and tear strength after washing with the enzyme (4). Aslan and Körlü conducted an experimental work that determines the changes on denim fabric types with different technical properties after enzymatic washing processes performed in different conditions. In this study some parameters such as dimensional stability, number of picks and ends, change in color, average weight, level of staining and tear strength were considered (5). Card et al. investigated the effects of laundering on physical properties (pilling and edge abrasion) of washed denim fabrics. As a result of this study, the pre-washed jeans were more prone to pilling than the enzyme and stone washed jeans (6). In this article by Kan and Yuen, the performance properties (dimensional stability, tensile strength etc.) of stretch denim fabric under the effect of repeated home laundering practices was studied. Based on the results of tensile strength, it was revealed that the elastane content did not have a consistent effect on the tensile strength (7).

The most important quality problem in the clothing industry is the sewing strength. Similar to other textile products, for a denim confection, the choice of sewing thread is one of the important parameters affecting quality and sewing performance. There are many studies in the literature on sewing performance of denim fabrics. In these studies, generally the effects of sewing parameters (including sewing threads and sewing density) and fabric construction on the sewing performance (including sewing strength, seam shrinkage and seam slippage) of denim fabrics have been investigated (8-18).

As different from other studies in the literature, an experimental design was made including a lot of parameters with different levels in this study. This difference made the study original. Within the study context, the effects of different washing procedures on the fabric and sewing performance were evaluated separately for fabrics with and without elastane. Two different denim fabrics were sewed with three different sewing threads to investigate their sewing performance. Additionally, three different denim-washing processes were also used in order to see the effect of washing. Pre-washing and post-washing fabric tensile strengths and sewing strengths were tested using standard methods; the obtained results were evaluated graphically and statistically.

2. Material and Method

2.1.Material

In this study, two types of denim fabric and three types of sewing thread were used as raw material. The denim fabric constructions used in this study are given in Table 1. The properties of sewing threads are shown in Table 2. These fabric types and sewing threads were selected because oftheir common use in the denim industry.

Table 1. Properties of Denim Fabrics

Constructions	Fabric Type	
	Denim fabric with elastane	Denim fabric without elastane
Weave pattern	3/1 Z twill	3/1 Z twill
Raw material	98 % cotton, 2 % elastane	100 % cotton
Weight (g/m^2)	355	327
Warp density (yarn/cm)	33	40
Weft density (yarn/cm)	18	23
Warp yarn count (Ne)	10 Ring carded slub	14 Ring carded slub
Weft yarn count (Ne)	13 Ring carded+elastane (78dtex)	13 Ring carded

Table 2. Properties of Sewing Threads

Sewing Thread Type			Ticket no	Linear density (Tex)	Strength (cN/tex)
1	Upper thread	Polyester/polyester core-spun (PES/PES core-spun)	30	105	42.86
	Bottom thread	Polyester/polyester core-spun (PES/PES core-spun)	50	60	50.00
2	Upper thread	*Polyester/cotton core-spun (PES/CO core-spun)	30	105	35.24
	Bottom thread	*Polyester/cotton core-spun (PES/CO core-spun)	50	60	46.67
3	Upper thread	Polyester filament (PES filament)	30	80	64.94
	Bottom thread	Polyester filament (PES filament)	40	60	70.83

*PES/CO core-spun yarn is composed of 65% polyester and 35% cotton fibers approximately.

2.2. Method

Rinse, enzyme, and stone with enzyme washing processes, which are commonly used in the denim industry, were applied to sample fabrics. Details of all the washing instructions are given in Tables 3 and 4. Both fabric tensile strength and sewing strength tests were carried out before and after washing, according to EN ISO 13934-1 and EN ISO 13935-1 respectively. The sewing parameters are shown in Table 5.

Table 3. Enzyme Washing and Stone Washing with Enzyme Instructions

Order of procedure	Name of the Procedure	Enzyme washing	Stone washing with enzyme	Flotte ratio (kg/L)	Temp (°C)	Duration (minutes)	pH	Chemical	
								Name	Amount
1	Desizing	available	available	1/8	45	14	6-7	-**Amylase enzyme** LAVAZYME AEN 01 KAISER (DYSTAR) -**Dispersant** LAVASPERSE KKC KAISER (DYSTAR)	0.4 cc/l 1.25 cc/l
2	Discharge	available	available						
3	Rinse washing	available	available	1/14	20	2	6-7		
4	Discharge	available	available						
5	Rinse washing	available	available	1/14	20	2	6-7		
6	Discharge	available	available						
7	Centrifuge	available	available						
8	Enzyme washing	available	unavailable	1/8	45	25	6-7	-**Neutral stone enzyme** ATB 96L (GARMON) -**Dispersant** LAVASPERSE KKCKAISER (DYSTAR) -**Defoamer** ANTISPUMIN DNF (BOZZETTO)	1.25 cc/l 1.25 cc/l 0.4 cc/l
	Stone washing with enzyme	unavailable	available	1/8	45	30	6-7	**-Neutral stone enzyme (cellulose)** ATB 96L (GARMON) **-Dispersant** LAVASPERSE KKC KAISER (DYSTAR) -**Defoamer** ANTISPUMIN DNF (BOZZETTO) -New pumice stone -Old pumice stone	1.25 cc/l 1.25 cc/l 0.4 cc/l 70% 70%
9	Discharge	available	available						
10	Rinse washing	available	available	1/14	20	2	6-7		
11	Discharge	available	available						
12	Rinse washing	available	available	1/14	20	2	6-7		
13	Discharge	unavailable	available						
14	Centrifuge	available	available						
15	Stone extraction	unavailable	available						
16	Rinse washing	unavailable	available	1/14	20	2	6-7		
17	Discharge	unavailable	available						
18	Centrifuge	unavailable	available						
19	Drying	available	available		70	60			

Table 4. Rinse Washing Instructions

Order of procedure	Name of procedure	Flotte ratio (kg/L)	Temperature (°C)	Duration (minutes)	pH
1	Rinse washing	1/14	20	5	6–7
2	Discharge				
3	Centrifuge				
4	Drying		70	60	

Table 5. Parameters of Sewing

Type of sewing machine	JUKI DDL-5550N-3
Type of stitch	Type 301-lock stitch
Stitches density (stitch / cm)	5
Type of sewing needle	Schmetz SPI-DF5
Number of sewing needle (metric)	100

All test results in warp and weft directions were discussed graphically and statistically. Multivariate ANOVA (MANOVA) tests with SPSS 20.0 software package were applied to determine the statistical significance of the test results. Before the application of the MANOVA test, the suitability of weft and warp fabric tensile strengths with normal distribution was analyzed using K–S tests and histogram graphs.

3. Results and Discussion

3.1.Fabric Tensile Strength Properties

In the study, pre-washing and post-washing fabric tensile strength values of the sample fabrics were determined and the results are shown in Figure 1.

Pre-washing and post-washing weft fabric tensile strength values in fabrics with elastane were lower than those in fabrics without elastane as expected. This result was associated with using elastane in the weft direction. Also, enzyme washing, and stone washing with enzyme, decreased the strength in fabric with elastane, and this result may be related to the damaged elastane in the weft thread due to washing. However, no changes in the weft strength of fabric without elastane after the washing process showed that weft threads in fabric without elastane were not affected by the washing process (due to the woven structure of the fabric being warp-dominant twill).

Pre-washing and post-washing warp fabric tensile strength values for fabric with elastane were generally close to those obtained in fabrics without elastane. As seen in Figure 1, the lowest values of warp fabric tensile strength values, in fabrics with and without elastane were obtained after stone washing with enzyme. This result may be related to the denim fabrics being warp-dominant at the surface, and the structurally damaged warp threads after stone washing with enzyme. Additionally, in also thestudy in the literature, it has been reported that the highest loss in fabric tensile strength among all the washing methods occurred whenstone washing with enzyme(2). On the other hand, it was seen that rinse washing in the weft and warp directions caused the minimum loss of fabric tensile strength, as in the following work (3).

Before the application of the MANOVA test, the suitability of weft and warp fabric tensile strengths of normal distribution was analyzed using K-S tests and histogram graphs. K-S test results in Table 6 showed that both weft and warp fabric tensile strength variables except weft direction with elastane have normal distributions because of sig.>0,05. However, when normality evaluations are made, if the data are numerically large, graphical methods should be also taken into account (19). For this reason, histogram graphics given in Figure 2 were obtained with statistical programme. When K-S test results and histogram graphics are evaluated together it was observed that the data showed normal and close to normal distributions. Because, according to the Central Limit Theorem, if the number of data is sufficient, having a single mode and if the curve is bell-shaped, despite of K-S test sig value<0,05, the data distribution are accepted as normal (19, 20, 21).

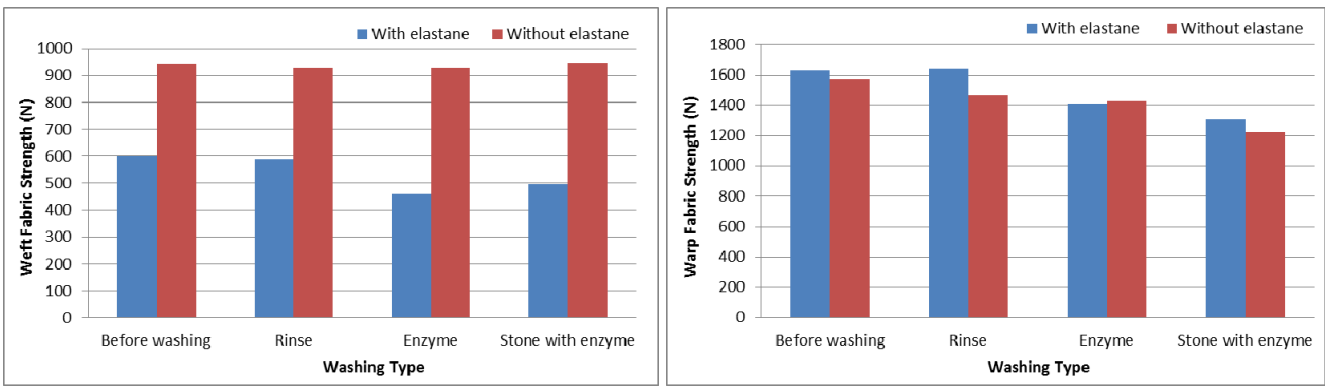
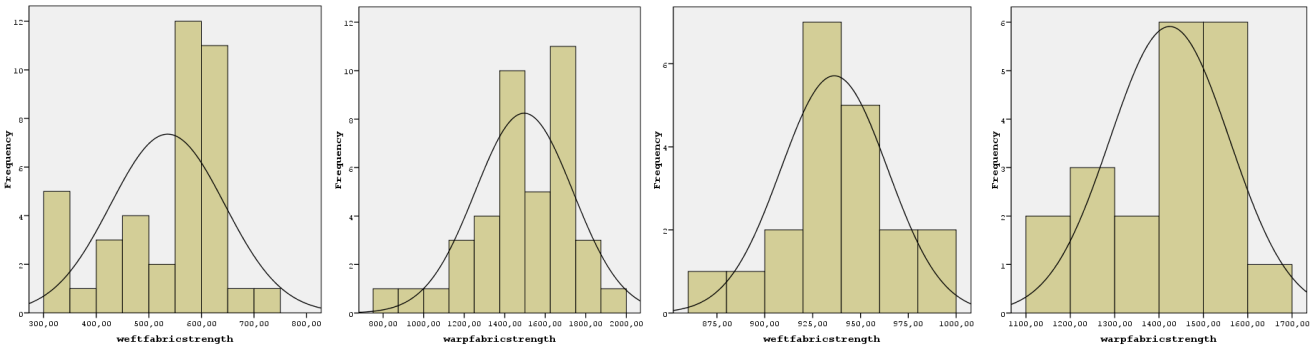


Figure 1. The changes in Weft and Warp Fabric Tensile Strength According to the Washing Type

Table 6. One-Sample Kolmogorov-Simirnov (K-S) Test Results (Fabric Tensile Strengths)

Dependent Variable	*Asymp.Sig.(2-tailed)*	
	Fabric without Elastane	***Fabric with Elastane***
Weft Fabric Tensile Strength	*,659*	*,028*
Warp Fabric Tensile Strength	*,445*	*,679*



(a) data obtained from fabric with elastane (b) data obtained from fabric without elastane

Figure 2. Normal Distribution Curves for Weft and Warp Fabric Tensile Strength Values

In the statistical analysis of the relationships between the fabric tensile strength and washing type, multivariate analysis of variance tests were primarily used. Test results for the relationship between the variables for fabric tensile strengthare given in Table 7. According to the table, the difference between the relationship for the washing type and warp fabric tensile strength values, in fabrics with and without elastane, were statistically significant (Sig.<0.05). On the other hand, the washing type had a significant effect on the weft fabric tensile strength in fabrics with elastane, whereas it had no significant effect in fabrics without elastane (Sig.>0.05).

Multiple comparison results are given in Table 8 depending on the type of washing. In fabrics with elastane – as the fabric tensile strength in the weft direction values did not show a homogeneous distribution – Tamhane test results were evaluated, whereas Tukey HSD test results were evaluated in the warp direction, as the variance values there showed a homogeneous distribution (19, 20, 21). In fabrics without elastane, variance values of fabric tensile strength in the weft and warp directions showed homogeneous distribution, therefore Tukey HSD test results were employed.

Table 7. Tests of Between-Subjects Effects for Fabric Tensile Strength

Source	Dependent Variable	Fabric without Elastane		Fabric with Elastane	
		F	Sig.	F	Sig.
Corrected Model	Weft[a]	,335	*,800*	5,540	*,003*
	Warp[b]	53,823	*,000*	6,380	*,001*
Intercept	Weft	20097,171	*,000*	1316,450	*,000*
	Warp	20796,826	*,000*	2160,985	*,000*
Washing Type	Weft	,335	*,800*	5,540	*,003*
	Warp	53,823	*,000*	6,380	*,001*
a R Squared = ,059 (Adjusted R Squared = -,117) (for fabric without elastane)					
b R Squared = ,910 (Adjusted R Squared = ,893) (for fabric without elastane)					
a R Squared = ,316 (Adjusted R Squared = ,259) (for fabric with elastane)					
b R Squared = ,347 (Adjusted R Squared = ,293) (for fabric with elastane)					

The mean difference is significant at the 0.05 level.

Table 8. Multiple Comparisons

Dependent Variable	Washing Type	Washing Type	Fabric without Elastane	Fabric with Elastane
			Sig.	***Sig.***
Weft Fabric Tensile Strength	Before Washing	Rinse	*,946*	*,999*
		Enzyme	*,946*	***,033***
		Stone with Enzyme	*,993*	*,148*
	Rinse	Enzyme	*1,000*	***,043***
		Stone with Enzyme	*,846*	*,191*
	Enzyme	Stone with Enzyme	*,844*	*,980*
Warp Fabric Tensile Strength	Before Washing	Rinse	***,011***	*,999*
		Enzyme	***,001***	*,096*
		Stone with Enzyme	***,000***	***,007***
	Rinse	Enzyme	*,529*	*,072*
		Stone with Enzyme	***,000***	***,005***
	Enzyme	Stone with Enzyme	***,000***	*,709*

The mean difference is significant at the 0.05 level.

According to the results for fabric with elastane, the changes between pre-washing and enzyme washing in weft fabric tensile strength values that were statistically significant (sig.<0.05) similarly as between enzyme and rinse washing results. Accordingly, in fabrics with elastane, the elastane used in the weft direction was disturbed with enzyme washing and, the weft fabric tensile strength was reduced as significant statistically.

In warp fabric tensile strength, the relationships between stone with enzyme-before washing and stone with enzyme-rinse values were statistically significant for both fabrics. The changes in warp fabric tensile strength values (except rinse-enzyme), according to multiple comparisons of washing types, were statistically significant whereas bilateral relationships between the weft fabric tensile strength values were not statistically significant for fabric without elastane.

3.2. Sewing Strength Properties

In the study, test results for sewing strength applied to the washed and non-washed fabrics using three different sewing threads are shown graphically in Figure 3 for two types of fabric samples. According to these, in general, the highest sewing strength values were obtained before washing, and the lowest values were seen after stone washing with enzyme, as seen the literature (13). The sewing strength of the warp direction was higher than the weft direction. The graphical analyses demonstrated that the washing type and sewing thread type had effects on sewing strength values. It was generally seen that the effect of the sewing thread on the seam strength was higher in the warp direction, like the previous study (15). It was observed that all washing processes including rinse, which is a simple washing process without any chemicals, significantly reduced weft and warp sewing strengths. The decrease in sewing strength after all the washing processes was much higher than the decrease in fabric strength. It was considered that all of the sewing threads were damaged by the washing processes and their strength decreased. It was also observed that sewing threads exhibited different effects according to the type of washing and the presence of elastane.

Furthermore, Multivariate ANOVA (MANOVA) tests using the SPSS 20.0 software package were applied to determine the statistical significance of these effects. K–S test results and histogram graphics in Table 9 and Figure 4 respectively indicate that the data of the variables showed normal and close to normal distribution.

According to the statistical results given in Table 10 for fabrics with elastane, the effect of the washing type and sewing thread type on the warp and weft sewing strength was found to be significant statistically. In addition to this, for fabric without elastane, all relationships were also found to be significant, except the sewing thread type and the weft sewing strength. On the other hand, the effect of the interaction between washing type and sewing thread type on weft and warp sewing strengths were found not to be significant for fabrics with elastane, whereas this effect was shown to be significant for fabrics without elastane.

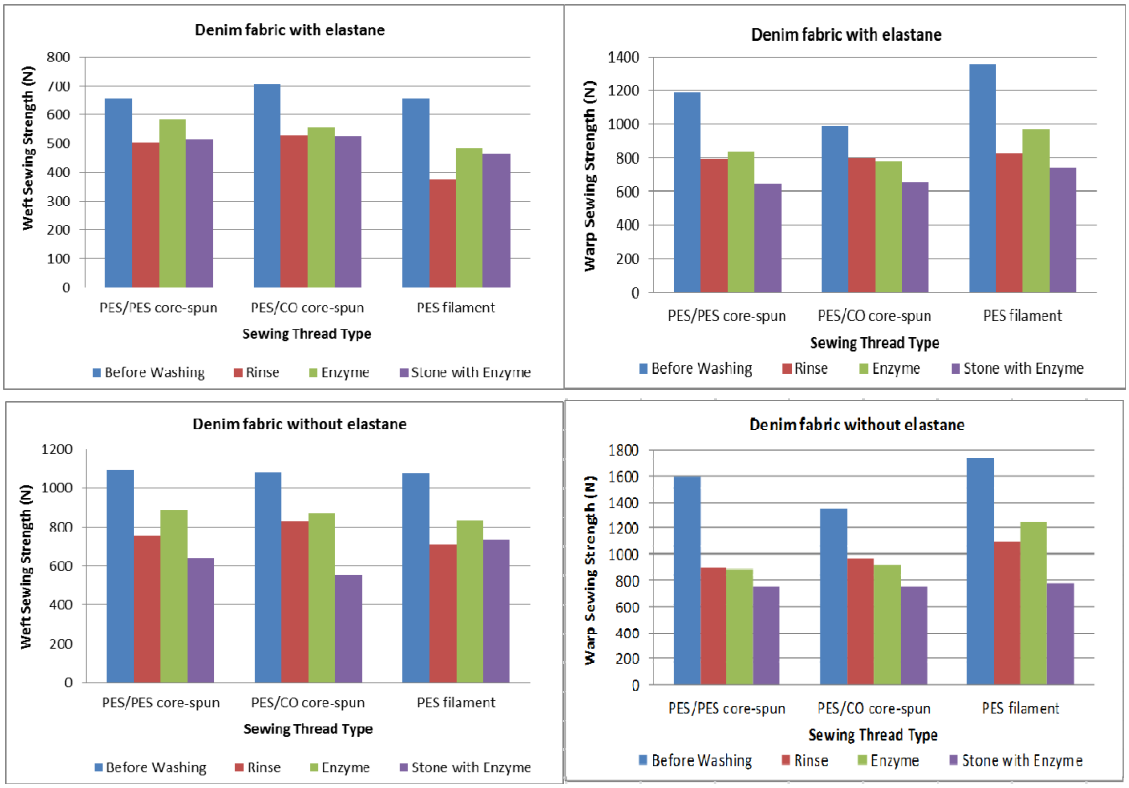
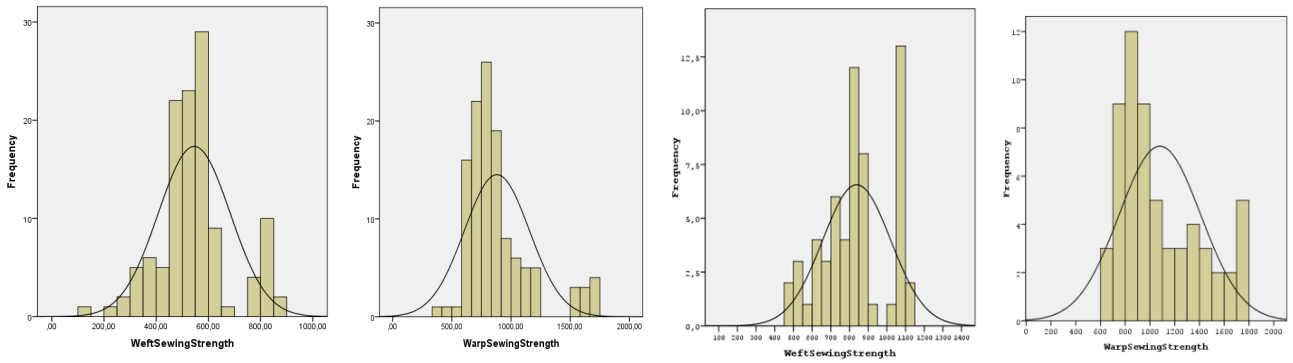


Figure 3. The Changes in Weft and Warp Fabric Tensile Strength According to the Washing Type and Sewing Thread

Table 9. One-Sample Kolmogorov-Simirnov (K-S) Test Results (Sewing Strengths)

Dependent Variable	*Asymp.Sig. (2-tailed)*	
	Fabric without Elastane	***Fabric with Elastane***
Weft Sewing Strengths	*,280*	*,018*
Warp Sewing Strengths	*,088*	*,000*



(a) data obtained from fabric with elastane (b) data obtained from fabric without elastane

Figure 4. Normal Distribution Curves for Weft and Warp Sewing Strength Values

Table 10. Tests of Between-Subjects Effects for Sewing Strength

Source	Dependent Variable	Fabric without Elastane		Fabric with Elastane	
		F	Sig.	F	Sig.
Corrected Model	Weft[a]	25,265	***,000***	7,087	***,000***
	Warp[b]	64,768	***,000***	11,846	***,000***
Intercept	Weft	6998,155	***,000***	2932,104	***,000***
	Warp	8266,556	***,000***	2466,509	***,000***
Washing Type	Weft	85,653	***,000***	19,809	***,000***
	Warp	203,016	***,000***	35,353	***,000***
SewingThread	Weft	,083	*,920*	6,621	***,002***
	Warp	31,482	***,000***	7,554	***,001***
WashingType * SewingThread	Weft	3,465	***,006***	,882	*,511*
	Warp	6,740	***,000***	1,523	*,177*
a. R Squared = ,853 (Adjusted R Squared = ,819) (for fabric without elastane)					
b. R Squared = ,937 (Adjusted R Squared = ,922) (for fabric without elastane)					
a. R Squared = ,419 (Adjusted R Squared = ,360) (for fabric with elastane)					
b. R Squared = ,547 (Adjusted R Squared = ,501) (for fabric with elastane)					

The mean difference is significant at the 0.05 level.

Multiple comparison results are given in Table 11, according to washing type, and in Table 12, according to the sewing thread. As the variance of weft and warp sewing strength values of fabrics with and without elastane did not show a homogeneous distribution, Tamhane test results were evaluated in Table 11(19, 20, 21). In Table 12, Tukey HSD test results were used as the variance of weft sewing strength values in fabric with elastane did show a homogeneous distribution, whereas Tamhane test results were used as the variance of warp sewing strength values did not show a homogeneous distribution. In fabrics without elastane, Tukey HSD test results are shown in Table 12 where the variance of weft and warp sewing strength showed a homogeneous distribution.

Table 11. Multiple Comparisons for Washing Type

Dependent Variable	Washing Type	Washing Type	Fabric without Elastane	Fabric with Elastane
			Sig.	*Sig.*
Weft Sewing Strength	Before Washing	Rinse	***,000***	***,000***
		Enzyme	***,000***	***,000***
		Stone with Enzyme	***,000***	***,000***
	Rinse	Enzyme	***,024***	***,007***
		Stone with Enzyme	***,020***	*,871*
	Enzyme	Stone with Enzyme	***,000***	*,567*
Warp Sewing Strength	Before Washing	Rinse	***,000***	***,000***
		Enzyme	***,000***	***,000***
		Stone with Enzyme	***,000***	***,000***
	Rinse	Enzyme	*,998*	*,356*
		Stone with Enzyme	***,000***	***,000***
	Enzyme	Stone with Enzyme	***,001***	***,000***

The mean difference is significant at the 0.05 level.

Table 12. Multiple Comparisons for Sewing Thread Type

Dependent Variable	Sewing Thread Type	Sewing Thread Type	Fabric without Elastane	Fabric with Elastane
			Sig.	Sig.
Weft Sewing Strength	PES/PES core-spun	PES/CO core-spun	*,984*	*,904*
		PES filament	*,998*	*,053*
	PES/CO core-spun	PES filament	*,994*	***,017***
Warp Sewing Strength	PES/PES core-spun	PES/CO core-spun	*,919*	*,658*
		PES filament	*,200*	*,326*
	PES/CO core-spun	PES filament	*,093*	***,008***

The mean difference is significant at the 0.05 level.

The changes between pre-washing and all the each other washing types, in both weft and warp sewing strength values, in fabrics with and without elastane, were statistically significant (Sig.<0.05). As can be seen in Figure 3, post-washing weft and warp sewing strength values decreased.

According to multiple comparisons for sewing thread types, the changes in both weft and warp sewing strength values of PES/CO core-spun and PES filament sewing threads were statistically significant (sig.<0.05) for fabrics with elastane. The differences between other sewing thread types were not statistically significant. In fabrics without elastane, the differences between all the sewing thread results, in both weft and warp sewing strength values, were not statistically significant.

4. Conclusion

Denim garments are subjected to washing to obtain specific appearance and handle. Different washing processes may lead to changes in fabric properties. In addition, sewing thread properties are an effective parameter on sewing performance. The aim of the study is to investigate the effects of sewing yarn and washing type on strength (fabric and sewing) in denim fabrics. The important results obtained with the experimental and statistical analyses are summarized below:

- Statistical analysis results showed that washing type had a significant effect on the weft fabric tensile strength in fabrics with elastane. No changes were observed in weft fabric tensile strength values in fabrics without elastane after washing.
- Examining the warp fabric tensile strengths, pre-washing values for fabrics with and without elastane were close to each other. Because, the constructions of the fabrics were very similar to each other and using elastane in the weft direction had no effect on the warp fabric tensile strength.
- The lowest values of warp fabric tensile strength in fabrics with and without elastane were obtained after the stone washing with enzyme process.
- According to the statistical analysis results, the relationship between the washing type and warp fabric tensile strength were statistically significant in fabrics with and without elastane.
- In general, the highest sewing strength values were obtained before washing, and the lowest values were seen after stone washing with enzyme for fabrics with and without elastane.
- According to the statistical results for fabric with elastane, the effect of the washing type and sewing thread type on the warp and weft sewing strength was found to be significant. On the other hand, the interaction between washing type and sewing thread type on weft and warp sewing strengths were not found to be significant for fabrics with elastane.
- For fabrics without elastane, all the relationships were also found to be significant, except the sewing thread type – the weft sewing strength relationship. On the other hand, the interaction between washing type and sewing thread type on weft and warp sewing strengths were found to be significant.
- The sewing thread giving the highest warp sewing strength values in all washing types was the polyester filament sewing thread, which had the highest yarn strength among the sewing threads used in the study.

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Postscript

Some results of the study were presented as a poster presentation at "International Conference on Future Technical Textiles (FTT 2014)", October 15 – 17, 2014, İstanbul, TURKEY(22).

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