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# Subjective Handle Scores for a Database of Next-to-Skin Knitted Fabrics



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April, 2010

## CRC Project 2.3

### Executive Summary

Twelve (12) judges experienced in handling knitted fabrics graded 52 next-to-skin knitted fabrics for the following characteristics:

- Overall Handle;
- Rough – Smooth;
- Hairy – Clean;
- Hard – Soft;
- Warm – Cool;
- Heavy – Light;
- Tight – Loose;
- Greasy – Dry.

The judges showed very good levels of sensitivity in assessing these handle characteristics. There were also strong to reasonable levels of agreement amongst the judges about their grading of the different handle characteristics. The strongest levels of agreement were for 'Smoothness', 'Overall Handle' and 'Softness'. The strength of their agreement gradually reduced through 'Heaviness', 'Hairiness', 'Tightness', 'Greasiness' to 'Warm – Cool' feel.

There was a clear preference for 'Soft', 'Smooth', 'Slick' handle in these fabrics, with a trend to prefer 'Loose' and 'Light' fabrics, though 'Hairiness' and 'Warm – Cool' feel had little, if any, effect on overall handle preferences.

While it is also acknowledged that there is variation amongst the judges in their assessments and their preferences for overall handle, the consensus shown by the judges provides scope for a prediction of these fabric handle characteristics based on testing of the physical properties of fabrics by instruments such as the Phabrometer.

# Subjective Handle Scores for a Database of Next-to-Skin Knitted Fabrics

Trevor Mahar & Henry Wang

April, 2010

## Introduction

A previous report<sup>1</sup> outlined a set of fabric handle descriptors which were considered important by judges experienced in the commercial assessment of the handle of next-to-skin knitted fabrics.

This report is a summary of the fabric handle assessments of the chosen seven (7) bipolar descriptors as well as overall fabric handle for a set of 52 next-to-skin knitted fabrics by experienced fabric handle judges.

## Method & Materials

As noted in the previous report<sup>1</sup> a set of 52 knitted fabrics in the weight range from 140gm<sup>-2</sup> to 210gm<sup>-2</sup> was assembled for assessment by the experienced judges. The fabrics were mainly pure wool and predominantly single jersey, and generally regarded as suitable for next-to-skin wear. The twelve (12) assessors experienced in handling fabrics were asked to rate the fabrics for overall fabric handle and six (6) primary handle characteristics plus their Greasiness – Dryness. The Greasy–Dry assessment was included with the handle characteristics as it was considered a quality control parameter as outlined in the previous report<sup>1</sup>. The characteristics, which were presented as bipolar word pairs, were:

Rough – Smooth;  
Hairy – Clean;  
Hard – Soft;  
Warm – Cool;  
Heavy – Light; and,  
Loose – Tight.

Judges were asked to assess the fabrics according to their usual method and rate them according to the scales shown in Table 1.

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<sup>1</sup> Summary of Fabric Handle Preferences – Next-to-Skin Knitted Fabrics, T.J. Mahar & H. Wang, sheep.crccentric.com.au, Project 2.3, Documents, December, 2009.

Table 1. Grading Scales – CRC Fabric Handle Assessments – 2009

### CRC Fabric Handle Assessments

#### Grading Scales

<b>Overall Fabric Handle</b>		<b>Smooth - Rough</b>		<b>Hairy - Clean</b>	
10	Excellent	10	Extremely Smooth	10	Brushed/raised
9	Very good	9	Very Very Smooth	9	Extremely Hairy
8	Good	8	Very Smooth	8	Hairy
7	Above Average	7	Good Smoothness	7	Fuzzy
6	A	6	A	6	Moderately Fuzzy
5	V	5	V	5	Clean
4	E	4	E	4	Clean
3	Below Average	3	Rough	3	Clean
2	Well Below Average	2	Very Rough	2	Very Clean
1	Poor	1	Very Very Rough	1	Extremely Clean
0	Unsuitable				
<b>Soft - Hard</b>		<b>Warm - Cool</b>		<b>Heavy - Light</b>	
10	Extremely Hard	10	Extremely Warm	10	Extremely Heavy
9	Very Hard	9	Very Warm	9	Very Heavy
8	Hard	8	Warm	8	Heavier
7	Moderately hard	7	Moderately Warm	7	Heavy
6	Neutral Softness	6	Neutral Warm - Cool	6	Neutral Weight
5	Neutral Softness	5	Neutral Warm - Cool	5	Neutral Weight
4	Neutral Softness	4	Moderately Cool	4	Neutral Weight
3	Good Softness	3	Cool	3	Light
2	Very Good Softness	2	Very Cool	2	Very Light
1	Extremely Soft	1	Extremely Cool	1	Extremely Light
<b>Loose - Tight</b>		<b>*Greasy - Dry</b>			
10	Extremely Tight	10	Extremely Dry		
9	Very Tight	9	Dry		
8	Tight	8	Somewhat Dry		
7	Above ave	7	Neutral		
6	Ave	6	Neutral		
5	Ave	5	Neutral		
4	Below Ave	4	Slick		
3	Loose	3	Slick to Sleazy		
2	Very Loose	2	Sleazy		
1	Extremely Loose	1	Excessive finish		

In order to improve the readability of these results all 'Hard – Soft' ratings quoted in this report were inverted by the relationship shown in Appendix 1.

The effect of this change is to bring the 'Hard – Soft' grade into line with the Overall handle and fabric smoothness ('Rough – Smooth') grades while maintaining the integrity of the original grades, such that a higher grade is now desirable in each of these three (3) characteristics.

## Results and Comments

### Agreement amongst Judges about Average Fabric Handle Grades

Table 2(a) presents the mean for the assessments of each judge for Overall fabric Handle, the six (6) primary descriptors and perceived 'greasiness'. The average of Overall Handle assessments for all assessors was 6.0 which is the high end of 'average' defined in the rating scale for overall handle assessment. Similarly, assessors rated the fabrics as slightly smoother than the defined average, and as more dry than greasy based on the defined average. The average 'Hairiness', 'Softness', 'Warm-Cool', perceived weight and 'Looseness – Tightness' were all in the defined average ranges.

Table 2(a) also shows the range of average assessments for each judge for each characteristic. The range of Overall Handle ratings was from 4.8, 'Average', for Judge 10 to 7.3, 'Above Average', for Judge 2, so that there was an average difference between these judges in their assessment of the handle of the fabrics of 2.5 units. Similar differences ranging from 2.1 units (Warm - Cool) to 3.1 units (Hard – Soft) were found for each of the characteristics. These results indicate similar average responses for the grading of the 52 fabrics.

### Variation amongst Judges in Fabric Handle Grades

The standard deviation (SD) of a set of fabric grades is a measure of the distribution of grades about the mean grade, a larger SD indicating a greater spread of grades and a smaller SD a tighter distribution of grades. The distribution of grades for a particular fabric characteristic will reflect the sensitivity of an assessor for that particular fabric characteristic in the fabrics being assessed.

The SD's of the grades for each judge for each fabric handle characteristic are shown in Table 2(b). The average SD's of the 12 judges ranged from a low of 1.4 (or, more precisely, 1.37) for 'Hairy - Clean' to a high of 2.1 for Overall Handle. The results in Table 2(b) indicate that the assessors used a wider spread of ratings for Overall Handle than for all other characteristics; and they used particularly narrow ranges of ratings for 'Warm – Cool' and 'Hairy - Clean'.

The SD's in Table 2(b) for Overall Handle, 'Rough – Smooth' and 'Hard – Soft' range from 1.8 to 2.1, whereas the SD's for the remaining five characteristics are either 1.4 or 1.5. These differences indicate that the judges were able to grade Overall Handle, 'Rough – Smooth' and 'Hard – Soft' with more sensitivity than fabric hairiness, Warm-Cool feel, tightness, greasiness and perceived weight.

The average of the SD's of all handle characteristics for each judge in Table 2(b) shows that J2 & J8 (Mean SD = 2.2) displayed the highest average sensitivity in assessing all handle characteristics in the 12 judges, while J4 displayed the lowest sensitivity (SD = 0.9).

Table 2. The mean (a) and standard deviation (b) of each judge in assessing overall fabric handle and each of the fabric handle characteristics, and the average grade (a) and SD (b) of each judge and each characteristic.

(a)

Judge Number	Overall Handle	Rough - Smooth	Hairy - Clean	Hard - Soft	Warm - Cool	Heavy - Light	Loose - Tight	Greasy - Dry	Average
1	5.3	6.5	5.3	6.4	5.0	4.1	4.4	7.7	5.6
2	7.3	6.9	5.0	7.5	4.7	4.9	5.8	5.9	6.0
3	7.0	7.3	5.4	6.5	6.5	5.6	5.8	6.5	6.3
4	5.4	5.5	4.6	6.1	4.8	4.6	5.2	6.0	5.3
5	5.7	5.7	5.9	6.4	5.4	5.1	6.6	6.4	5.9
6	5.7	5.6		4.4	5.8	6.0	6.4	7.1	5.9
7	6.2	6.0	4.1	6.5	5.3	4.9	5.3	5.2	5.4
8	5.9	6.2	3.4	6.3	4.4	5.2	6.6	5.2	5.4
9	6.6	5.8	5.5	5.7	5.7	5.0	6.2	6.7	5.9
10	4.8	4.9	4.7	5.9	5.4	3.6		6.5	5.1
11	5.5	5.4	5.0	6.1	5.8	5.2		6.1	5.6
12	6.8	6.5	4.6	6.2	5.8	3.6		7.0	5.8
Average	6.0	6.0	4.9	6.2	5.4	4.8	5.5	6.4	5.6

(b)

Judge Number	Overall Handle	Rough - Smooth	Hairy - Clean	Hard - Soft	Warm - Cool	Heavy - Light	Loose - Tight	Greasy - Dry	Average
1	3.1	1.8	1.7	2.1	1.3	1.5	1.6	1.2	1.8
2	2.3	2.6	1.6	2.4	2.1	2.3	2.2	2.4	2.2
3	1.3	1.4	1.3	1.7	1.5	1.8	1.9	1.9	1.6
4	1.0	0.9	0.7	1.0	0.8	0.8	0.8	1.1	0.9
5	3.1	2.1	1.8	1.8	1.4	1.5	1.4	2.2	1.9
6	3.1	1.9		1.2	0.8	1.2	1.2	1.7	1.6
7	2.8	2.3	1.6	2.5	1.0	1.4	1.4	1.4	1.8
8	2.4	2.4	1.6	2.4	1.9	2.5	2.0	2.2	2.2
9	1.1	1.6	1.0	1.5	1.6	1.6	1.3	1.3	1.4
10	1.5	1.5	1.1	1.3	1.3	1.0		1.6	1.3
11	1.2	1.7	1.4	1.5	1.3	1.2		1.7	1.4
12	1.9	2.0	1.3	1.9	1.5	1.4		2.1	1.7
Average	2.1	1.8	1.4	1.8	1.4	1.5	1.5	1.7	1.6

## Relationships Amongst Fabric Handle Ratings

Table 3 shows the correlation coefficients between pairs of average fabric handle characteristics. In this case the average of the assessments of the twelve (12) assessors has been calculated for each handle characteristic. These results show very strong linear relationships between Overall Handle and two (2) characteristics, fabric softness (Hard – Soft), correlation coefficient,  $r = 0.91$ , and fabric smoothness (Rough – Smooth),  $r = 0.83$ . There are also strong relationships between Overall Handle and 'Greasy – Dry' ( $r = -0.81$ ).

Table 3. The correlation coefficients between the average ratings of 12 assessors for Overall Handle and seven (7) fabric handle characteristics.

	Rough - Smooth	Hairy - Clean	Hard - Soft	Warm - Cool	Heavy - Light	Loose - Tight	Greasy - Dry
Overall Handle	0.83	-0.24	0.91	-0.24	-0.54	-0.59	-0.81
Rough - Smooth		-0.64	0.79	-0.64	-0.64	-0.37	-0.87
Hairy - Clean			-0.18	0.87	0.37	-0.19	0.44
Hard - Soft				-0.22	-0.67	-0.68	-0.82
Warm - Cool					0.58	-0.05	0.41
Heavy - Light						0.57	0.54
Loose - Tight							0.50

There were also strong relationships amongst some of the fabric characteristics. Fabric smoothness was related to fabric softness ( $r = -0.79$ ) and 'greasiness' ( $r = -0.87$ ). Fabric softness and greasiness ( $r = -0.82$ ), and 'Warm – Cool' and fabric hairiness ( $r = 0.87$ ) were also strongly correlated.

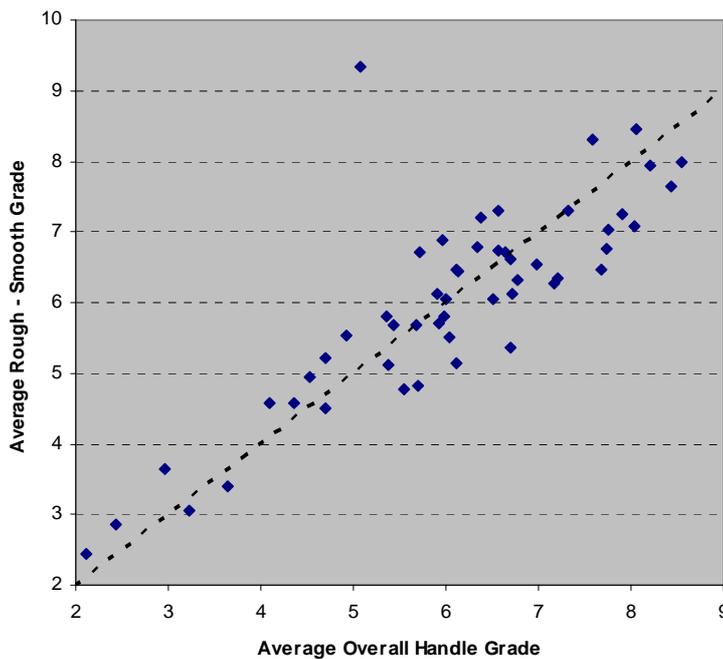
The very high correlations between Overall Handle and fabric smoothness and fabric softness indicate that these two characteristics have a very strong influence on Overall Handle grade. Judges clearly prefer smooth, soft fabric handle as shown graphically in Figure 1 (a) and (b), which also features a ( $Y = X$ ) dashed line indicating where there is complete agreement between the grades on each axis. It is interesting that one fabric does not conform to the strong linear relationship shown in Figure 1 (a). This fabric is composed of 100% filament viscose and has the highest average grade for 'Rough – Smooth', viz 'Extremely Smooth', but has only an average Overall Handle grade.

The correlation coefficients between Overall Handle and the remaining fabric characteristics fall into two categories - weak trends with 'Heavy – Light' and 'Tight – Loose', and poor relationships with 'Hairy – Clean' and 'Warm – Cool'. A visual illustration of the relationships between Overall Handle and the fabric handle characteristics, hairiness, Warm-Cool feeling, perceived weight and tightness, are shown in Figure 1 (c), (d), (e) and (f).

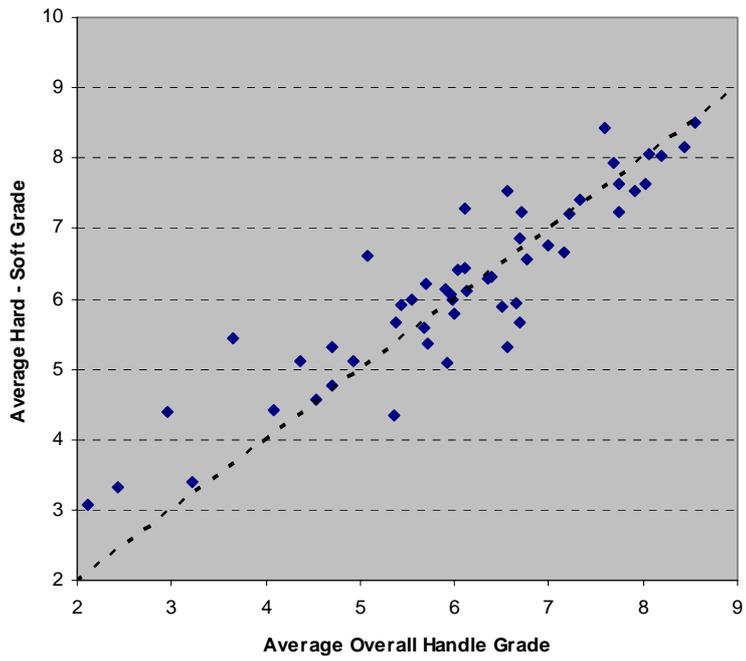
The moderate negative trend quantified by the correlation coefficient of  $-0.54$  is shown in Figure 1(e), which highlights that heavier fabrics tend to have poor Overall Handle and lighter fabrics good Overall Handle. In particular, all fabrics with an Overall Handle grade  $<3.5$  ('Below Average') were assessed as 'Neutral' to 'Heavy'. Similarly, the moderate negative trend for Overall Handle to be related to fabric tightness ( $r = -0.59$ ) is shown in Figure 1(f). Tighter fabrics tend to have poorer Overall Handle grades in this fabric set.

The relatively 'flat' relationship ( $r = -0.24$ ) between Overall Handle and 'Hairy – Clean' can be seen in Figure 1 (c), which also highlights the relatively narrow band of hairiness grades assessed for these fabrics, with most fabrics in the range 3.5 (Clean) to 6.5 (Moderately Fuzzy). Similarly, Figure 1(d) shows a 'flat' relationship ( $r = -0.24$ ) between Overall Handle and 'Warm – Cool'. In this case most fabrics fall into the narrow range from 4 ('Moderately Cool') and 6.5 ('Neutral' to 'Moderately Warm'). An exception is the 'Extremely Smooth' 100% viscose filament fabric which had an average rating of 2.6 ('Cool' to 'Very Cool').

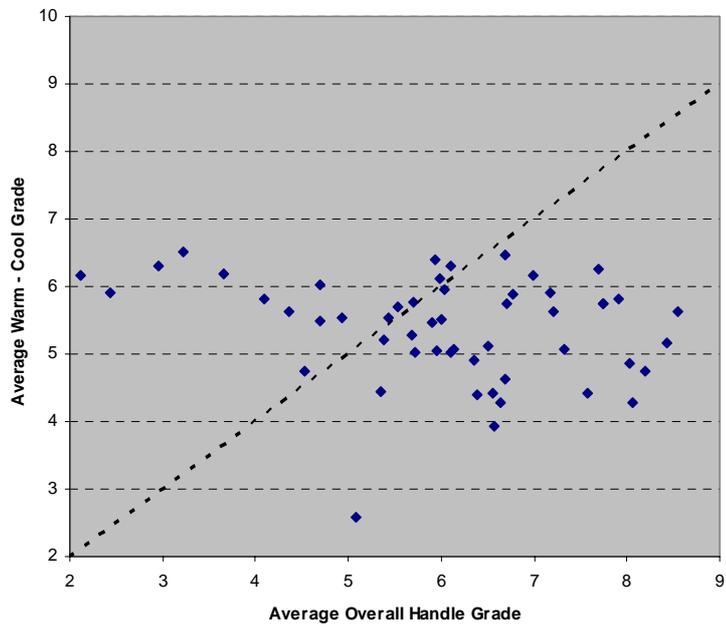
(a) Overall Handle v Rough - Smooth



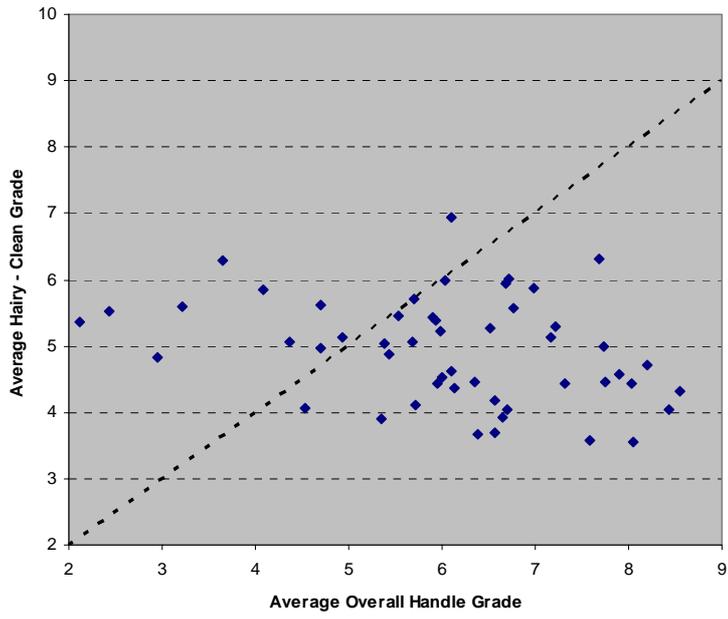
(b) Overall Handle v Hard - Soft



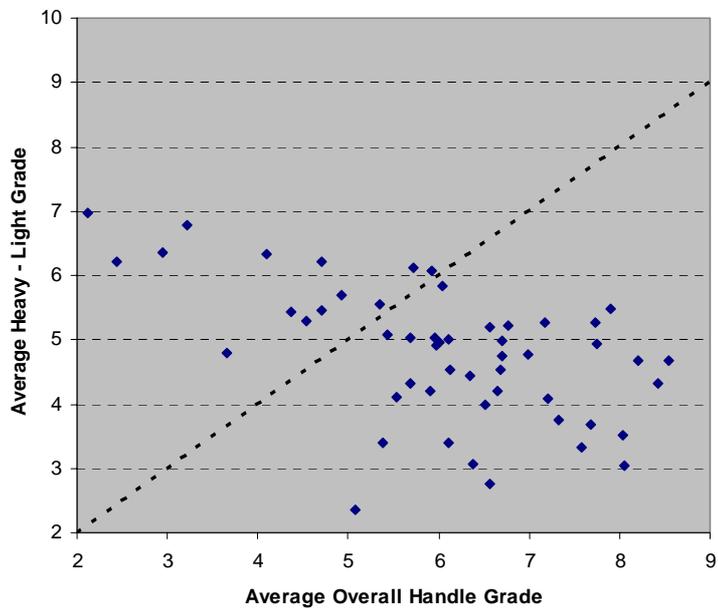
(c) Overall Handle v Warm - Cool



(d) Overall Handle v Hairy - Clean



(e) Overall Handle v Heavy - Light



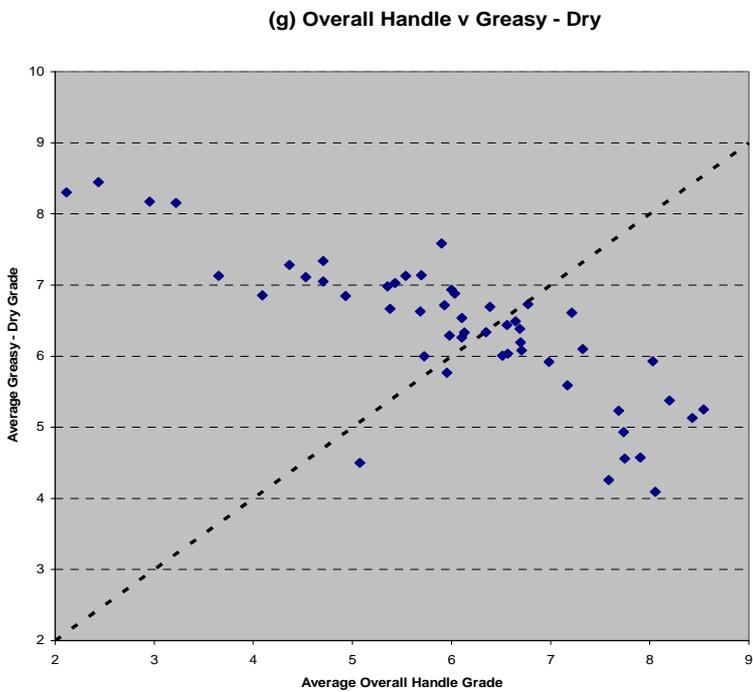
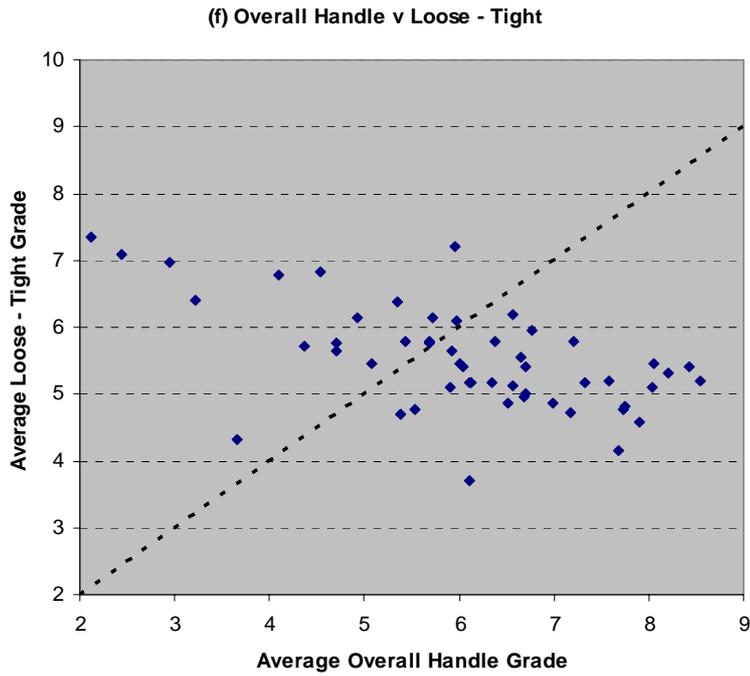


Figure 1 (a) – (g). Relationships between the average Overall Handle of the 12 experienced judges and their average grades for the selected fabric handle characteristics.

The high negative correlations of 'Greasy – Dry' with Overall Handle ( $r = -0.81$ ), as shown in Figure 1(g), and with fabric smoothness ( $r = -0.87$ ) and softness ( $r = -0.82$ ) are not unexpected as this characteristic was included in the trial because of its importance as a quality assurance measure to detect if excessive amounts of softener had been added to a fabric. As the name implies, softeners are added to fabrics in order to increase the fabric softness and improve the desirability of (overall) fabric handle. Softeners may also increase perceived fabric smoothness but softeners can make the fabric surface unpleasantly greasy.

## Agreement Amongst Judges in Fabric Handle Rankings

### Overall Handle

In the context of this analysis correlation coefficients are a measure of the level agreement in ranking fabrics between two grades of the characteristics under review. Tables 4 and 5 show the correlation coefficients between the Overall Handle assessments of each assessor and either their own assessment of each handle characteristic (Table 4) or the average assessment of all twelve (12) assessors for each handle characteristic (Table 5).

An important result in Table 5 is the correlation of each judge's Overall Handle grades with the average Overall Handle grades of the full set of 12 judges. The average correlation of 0.75 with a range from 0.53 to 0.89 shows the high level of agreement amongst the 12 judges in their Overall Handle ranking of the fabrics. The strong level of agreement for these fabric handle grades indicated by these correlation coefficients signifies that these experienced judges have similar judgement of fabric handle.

Tables 4 and 5 also highlight that the Overall Handle preferences of the individual judges are strongly related to the average fabric smoothness (average  $r = 0.65$ ) and average fabric softness (average  $r = 0.68$ ) grading of all 12 judges. Indeed fabric softness was one of the two highest correlations of all the primary characteristics to Overall Handle for every judge, and this was the case for fabric smoothness for 10 of the 12 judges. The only other primary characteristic to feature in the highest two correlations with Overall Handle for each judge was fabric tightness on two occasions.

A further result shown in Tables 4 and 5 is that the individual judges had similar appreciation of the relationship between their Overall Handle grades and their primary characteristics as between their Overall Handle and the average primary characteristics of all 12 judges.

Table 4. Correlation coefficients between the Overall Handle assessments of each assessor and the individual assessor's assessment of each handle characteristic.

Judge Number	Rough - Smooth	Hairy - Clean	Hard - Soft	Warm - Cool	Heavy - Light	Loose - Tight	Greasy - Dry
J1	0.69	0.09	0.91	-0.08	-0.63	-0.70	-0.23
J2	0.65	0.19	0.68	0.55	0.06	-0.59	-0.69
J3	0.65	0.18	0.91	0.23	-0.54	-0.54	-0.62
J4	0.55	-0.37	0.48	-0.22	-0.21	-0.16	-0.61
J5	0.83	-0.39	0.82	-0.35	-0.38	-0.05	-0.68
J6	0.84		0.48	-0.45	-0.63	-0.30	-0.61
J7	0.81	-0.42	0.95	-0.52	-0.47	-0.18	-0.61
J8	0.23	-0.06	0.48	-0.29	-0.10	-0.29	0.18
J9	0.31	-0.27	0.33	-0.04	-0.13	-0.10	-0.29
J10	0.86	-0.67	0.60	-0.54	-0.40		-0.71
J11	0.75	-0.33	0.69	-0.09	-0.51		-0.64
J12	0.73	-0.33	0.45	0.21	-0.40		-0.49
Average	0.66	-0.22	0.65	-0.13	-0.36	-0.32	-0.50

Table 5. Correlation coefficients between the Overall Handle assessments of each assessor and the average assessment of all twelve (12) assessors for each handle characteristic.

Judge Number	Overall Handle	Rough - Smooth	Hairy - Clean	Hard - Soft	Warm - Cool	Heavy - Light	Loose - Tight	*Greasy - Dry
J1	0.89	0.77	-0.20	0.87	-0.26	-0.61	-0.53	-0.76
J2	0.77	0.46	0.13	0.68	0.14	-0.32	-0.66	-0.52
J3	0.84	0.73	-0.10	0.86	-0.14	-0.50	-0.61	-0.73
J4	0.74	0.78	-0.46	0.67	-0.41	-0.46	-0.30	-0.73
J5	0.69	0.68	-0.24	0.68	-0.28	-0.44	-0.30	-0.71
J6	0.69	0.68	-0.24	0.68	-0.28	-0.44	-0.30	-0.71
J7	0.88	0.70	-0.25	0.78	-0.22	-0.45	-0.48	-0.63
J8	0.72	0.38	0.11	0.55	0.10	-0.17	-0.48	-0.37
J9	0.53	0.46	-0.31	0.40	-0.19	-0.16	-0.13	-0.37
J10	0.76	0.69	-0.29	0.64	-0.25	-0.39	-0.39	-0.69
J11	0.79	0.83	-0.44	0.81	-0.47	-0.60	-0.44	-0.81
J12	0.66	0.64	-0.32	0.58	-0.30	-0.43	-0.42	-0.56
Ave	0.75	0.65	-0.22	0.68	-0.21	-0.41	-0.42	-0.63

## Primary Handle Characteristics of Fabrics

Table 6 shows the correlations between individual judge's grades and the average grades of all 12 judges for the six (6) primary characteristics of fabrics, and for fabric greasiness. The relatively high correlation coefficients in the Table indicate the strong overall agreement amongst the 12 judges in their grading of the Overall Handle, six primary handle characteristics of next-to-skin knitted fabrics and fabric greasiness.

Table 6. Correlations between individual judge's grades and the average grades of all 12 judges for the six (6) primary characteristics of fabrics and fabric greasiness.

Judge Number	Rough - Smooth	Hairy - Clean	Hard - Soft	Warm - Cool	Heavy - Light	Loose - Tight	Greasy - Dry
1	0.88	0.57	0.81	0.68	0.83	0.86	0.35
2	0.66	0.61	0.57	0.62	0.39	0.80	0.63
3	0.84	0.59	0.81	0.57	0.82	0.64	0.68
4	0.62	0.47	0.53	0.50	0.50	0.60	0.63
5	0.84	0.75	0.81	0.59	0.80	0.59	0.78
6	0.75		0.49	0.28	0.71	0.50	0.70
7	0.92	0.77	0.83	0.76	0.75	0.67	0.76
8	0.75	0.66	0.88	0.72	0.80	0.50	-0.01
9	0.79	0.50	0.80	0.54	0.81	0.51	0.69
10	0.78	0.56	0.69	0.63	0.52		0.67
11	0.69	0.74	0.75	0.50	0.62		0.67
12	0.76	0.78	0.71	0.13	0.62		0.56
Ave	0.77	0.64	0.72	0.54	0.68	0.63	0.59

## Conclusion

12 experienced judges have displayed high sensitivity and strong agreement amongst themselves in assessing Overall Handle, the six (6) primary characteristics of fabric handle previously found to be important in determination of the handle of next-to-skin fabrics, and fabric greasiness of a set of 52 fabrics.

The fabric handle characteristics used in subjective assessments of next-to-skin knitted fabrics have been shown to strongly influence the Overall Handle of fabrics. In particular, fabric smoothness and softness are strongly related to Overall Handle, though the bipolar word pairs 'Heavy – Light', 'Loose – Tight' and 'Dry – Clean' also have firm relationships with Overall Handle. 'Hairy – Clean' and 'Warm – Cool' assessments have relatively poor linear relationships with Overall Handle.

These results further indicate that sufficient consensus exists about fabric handle assessments to provide a basis for their prediction based on measurement physical properties of the fabrics. It is also acknowledged that there is variation amongst the assessors in their assessments and their preferences for overall handle.

## Appendix 1

Hard- Soft grades were altered by the following formula for all results reported in this trial:

$$(\text{'Hard - Soft' Grade})_{\text{new}} = 11 - (\text{'Hard - Soft' Grade})_{\text{original}}$$