

Q-max Test Analysis of Summer Cooling Towels

Yim-Ling Lam¹, Wenyi Wang^{1,a}, Chi-Wai Kan^{1,b*}, Thitima Puttabucha^{2,c},
Supanicha Srivorradatpaisan^{3,d}, Rattanaphol Mongkholrattanasit^{2,e}

¹Institute of Textiles and Clothing, The Hong Kong Polytechnic University, Hung Hom, Hong Kong, China

²Faculty of Industrial Textiles and Fashion Design, Rajamangala University of Technology Phra Nakhon, Bangkok, Thailand

³Faculty of Science & Technology, Rajamangala University of Technology Phra Nakhon, Bangkok, Thailand

wangwenyi1111@gmail.com^a, tccwk@polyu.edu.hk^b, thitima.p@rmutp.ac.th^c,
supanicha@windows.live.com^d, rattanaphol.m@rmutp.ac.th^e

*Corresponding Author, e-mail: tccwk@polyu.edu.hk

Abstract

This study evaluated the cooling properties of summer cooling towels of different brands by Q-max analysis. It was found all the samples could provide a cooling effect at first contact after being wetted. The samples of Perfect Fitness showed the highest cooling effect followed by the N-rit samples, whereas Street samples had the poorest cooling effect. The reason may be explained by the yarn density, fabric structure and thickness.

Keywords: Q-max test, cooling towel, fabric weight, fabric thickness

INTRODUCTION

Nowadays, consumers are increasingly concerned on the high-functional textile products apart from the aesthetic features, demanding breathable, coolness touching and quick dry fabric and clothing in summer [1]. Due to the hot weather in Hong Kong and increasing demand of functional products, cooling products are popular in recent years, particular the cooling towels which could be bought from sports chain stores, street stores and online shops. Various brands of this product emphasize the cooling effect and excellent cooling sensations of the towel which helps body stay cool during summer and sports time.

Cooling towels' function is achieved by the evaporation of water. It is simple to activate the cooling towel. The step is to soak the towel with the water, wring the excess water, snap it and then just place it around the neck when doing sports or just using during hot days [2]. Repeat the above steps when the cooling effect is no longer obvious.

Evaporative cooling towels are said to offer cooling effect helping body stay cool for hours by quick moisture absorption and evaporation of the heat out of the towel by water. In the market, many brands have used different functional fabrics to develop the cooling towels and all the cooling effect is activated with water. The representative brands include Perfect Fitness, N-rit and Cooldyxm, etc. This study aims to comparatively evaluate the cooling properties of cooling properties of four types of cooling towel products using Q-max analysis.

METHODOLOGY

Fabric specimen

Four cooling towels were obtained from four different brands through chain stores, online shop or street store in Hong Kong and China market. These tested products have different fiber contents, fabric structure and thickness but all of them provide the cooling function with water. The present study aims to compare the product of chain store with online store and street store. The specification of each sample was shown in Table 1.

All samples were conditioned with the temperature at $20 \pm 2^\circ\text{C}$ and the relative humidity at $65 \pm 2\%$ for 24 hours before testing

Table 1. Specification of tested samples.

Item	Sample specification			
Brand	Perfect Fitness	N-rit	Cooldyxm	Ice Towel
Composition	100% PVA	92% Polyester 8% Spandex	100% Polyester	100% Polyester
Size/cm	73×27	99×19.7	108×31	88×35
Type	Composite fabric	Knit	Knit	Knit
Fabric weight (g/m ²)	360.16	131.43	165.05	194.09
Fabric thickness/mm	1.95	0.40	0.61	0.62
Yarn linear density/ Tex	32.3	15.7	18.5	21.4
Fabric density	Wale/cm	7	18	17
	Course/cm	6	24	18

Surface morphology analysis

The surface morphology of fabric structure of selected brands samples were observed by the Digital Microscope (Leica DVM6, Hamburg, Germany).

Q-max test (KES-F7)

Q-max testing measures the instant warm or cool feeling of the fabric using KES-F7 Thermo Labo II. Q max value (peak heat flux) is evaluated by the heat transmission from the heat plate to the sample fabric, to imitate the sensation of fabric touched by hands and heat flow from human skin to the fabric. In this test, samples in dry and wet states were assessed. Higher q-max value indicates a cooler feeling.

First, KES-F7 Thermo Labo II was switched on and warmed up for about 10 to 15 minutes. The temperature in the water box should be circulated and kept at 20°C to 21°C . BT Box and guard temperature were set at 30°C and 30.4°C respectively. Then, the copper plate of T Box was

put above the copper plate of BT Box to start heating to designed temperature. The fabric piece was placed on the sample base in which the side that contacts skin was place upward. Afterwards, the qm button was pushed while the temperature of the T Box reached 30.1°C, then the T Box was moved and placed on the tested fabric piece accurately. The qm digital reading on the monitor was then recorded. All steps were repeated until 5 sample fabrics from each brand in both dry and wet conditions were assessed.

RESULT AND DISCUSSION

Fabric morphology analysis

The appearance of the samples were observed by using the microscope LEICA M165C, and shown in Figure 1. Clearly, the appearance of four samples were different. The fabric structure of samples were shown in Figure 2. The sample of Perfect Fitness was made of composite fabric with 2 layers (Figure 2A). In first layer, there are small pores on the fabric surface whereas there is a plain weave structure in second layer. N-rit has mesh effects formed by interrupting the loop wales (Figure 2B). Cooldyxm's towel was constructed in two layers and mesh weft knit with hexagon pattern on surface, and Ice Towel was constructed of a mesh weft knit with honeycomb pattern and it had two layers.

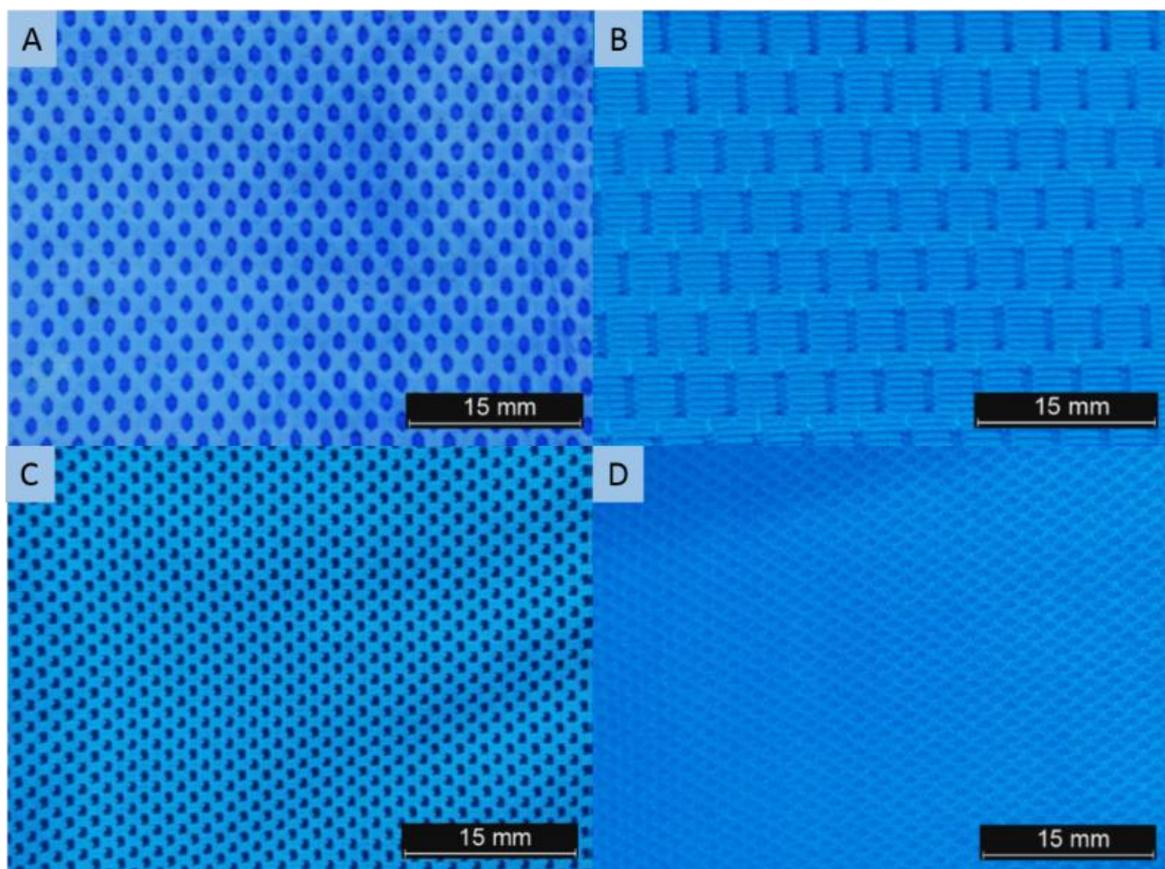


Figure 1. Fabric face appearance of samples of different brands: Perfect Fitness (A), N-rit (B), Cooldyxm (C) and Ice Towel (D).

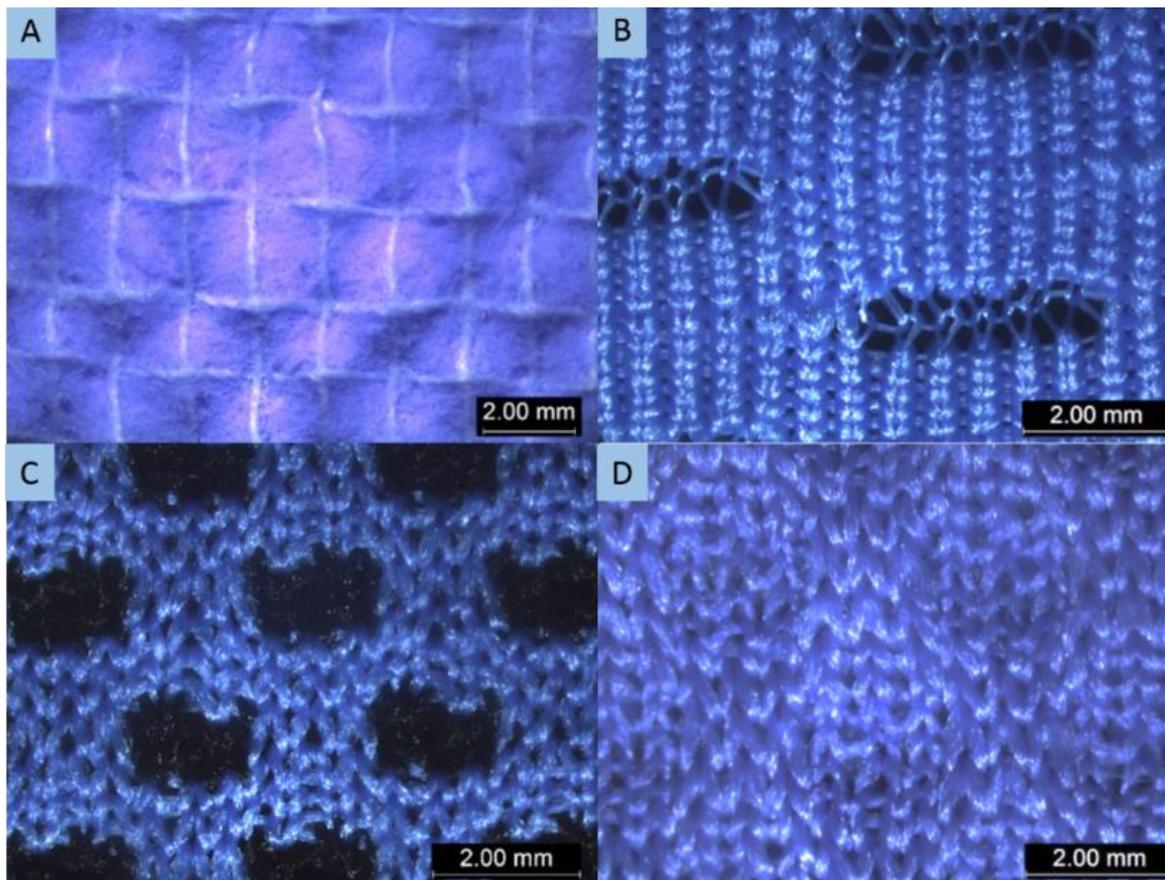


Figure 2. Fabric structure of samples of different brands: Perfect Fitness (A), N-rit (B), Cooldyxm (C) and Ice Towel (D).

Q-max test analysis

Based on the Q-max results in Figure 3, Perfect Fitness has the highest Q-max value of 0.164 and 0.381 J/cm²·sec in both dry and wet states respectively. N-rit has the second highest Q-max value which is 0.103 and 0.344 J/cm²·sec, followed by Cooldyxm (0.088 J/cm²·sec in dry state and 0.301 J/cm²·sec in wet state) and Street (0.082 J/cm²·sec in dry state and 0.290 J/cm²·sec in wet state). The highest mean wet Q-max to the lowest is 0.381 J/cm²·sec to 0.290 J/cm²·sec, and the difference is 0.09 J/cm²·sec. If Q-max of the fabric is more than 0.140 J/cm²·sec, it can be regarded as cool fabric which could provide instant coolness sensation. Since Q-max values of all four samples exceed 0.140 J/cm²·sec in wet state, they could provide a cooling effect at first contact after being wetted. Moreover, the sample of Perfect Fitness can provide the coolest instant sensation after wetting when compared to other three products since the higher the Q-max value, the cooler the touch feeling of the fabric with skins.

Relationship between Q-max in Dry and Wet States

Comparing dry and wet Q-max, it was found that all samples have higher Q-max value in wet state than that in dry state. This indicates that the sensation of all the towels was cooler after being wetted by water. As Hes & De Araujo [3] suggested that the greater cooling effect could be achieved by wet fabric due to the water content absorbed by the fabric, the towel in wet state can generate cooler touch feeling.

According to the correlation table from SPSS (Table 2), p-value is 0.000 ($\alpha = 0.005$), this indicating that there is a significant correlation between dry Q-max and wet Q-max. As the R-value equals to 0.880 ($r > 0.7$, strong relationship), the relationship is strong and positive. Therefore, it can be concluded that the higher the dry Q-max value, the greater the wet Q-max value of the fabric, and the better the coolness sensation it can provide through contacting the skin directly.

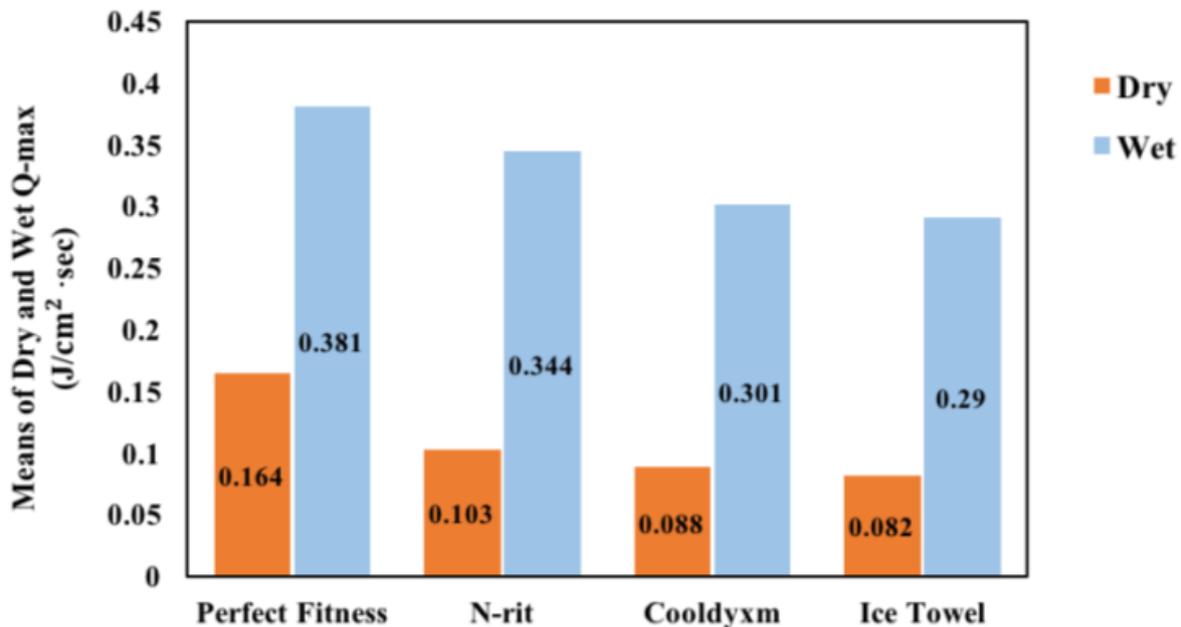


Figure 3. Mean value of dry and wet Q-max of four samples.

Table 2. Correlation between Q-max in dry and wet states.

		Dry Q-max (J/cm ² ·sec)
Wet Q-max (J/cm ² ·sec)	Pearson correlation	0.880**
	Sig. (2-tailed)	0.000

The relationship between dry Q-max and wet Q-max was shown in Figure 4. It can be found that wet Q-max values of the fabrics increase with the increase of dry Q-max, between which a positive linear relationship was shown. Wet fabric has higher coolness sensation than dry fabric, and it may be due to the evaporation of water in the wet fabric which can provide cooling effect to dissipate heat. It was also found that cooling effect was greater for wet fabric. The evaporation of sweat from skin would increase the surface area for evaporation and provide a greater skin cooling as shown in Figure 4.

The sample of Perfect Fitness has the highest dry Q-max, thus it also has the greatest wet Q-max value. Since the product of street shop has the poorest performance in dry Q-max, its average wet Q-max values are the lowest as well.

Relationship between water absorption and wet Q-max

Reischl & Goonetilleke [4] indicated that wet fabric with minimal amount of water can provide a greater instant cooling effect than the fabric with a large amount of water. However, this

behavior is not suitable to apply to this project case. It was found that wet Q-max is not correlated to the amount of water absorbed by the fabric (Table 3).

Since p-value was 0.329 ($>\alpha = 0.05$) and r-value equaled to 0.671, it is confident to prove that the amount of water absorption by the fabric was not correlated with the wet Q-max (Table 4).

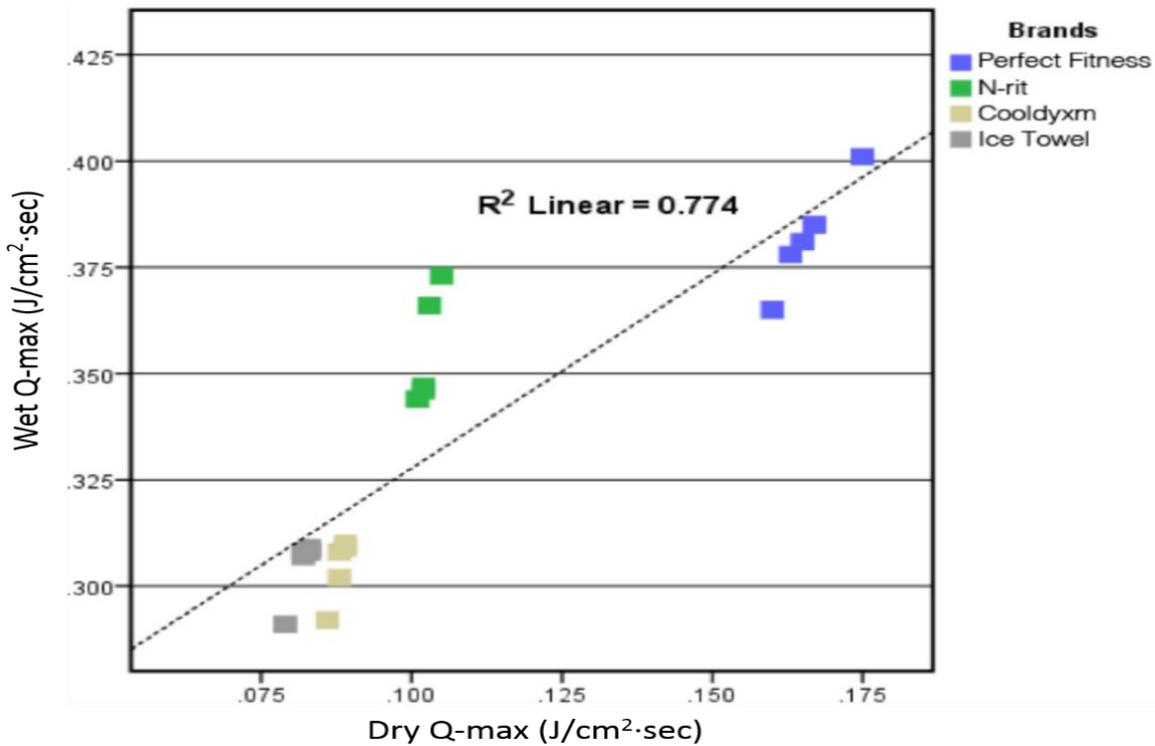


Figure 4. Relationship between dry Q-max and wet Q-max.

Table 3. Amount of water absorption of the fabrics (5×5 cm).

sample	Fabric weight/g		Water absorption/g
	Before wetting	After wetting	
Perfect Fitness	2.684	5.153	2.469
N-rit	0.863	2.008	1.145
Cooldyxm	1.037	2.259	1.222
Ice Towel	1.292	2.837	1.545

Table 4. Correlation between amount of water absorption and wet Q-max.

		Water absorption amount/g
Averaged wet Q-max (J/cm ² ·sec)	Pearson correlation	0.880**
	Sig. (2-tailed)	0.000

The plot in Figure 5 shows the relationship between the water absorbed by the fabric and wet Q-max. Though the amount of water absorption of N-rit is the lowest, the wet Q-max value is the higher than Cooldyxm and Ice Towel, both of which can absorb more water than that of N-rit. Although it is shown that higher water content absorbed by the fabric may not lead to a cooler instant sensation for the skin, fabric with higher water absorption capacity could offer and maintain

a longer cooling effect and sensation. This could be explained by the fact that more water held in the fabric and the longer time it requires to dry fabric, thus it can be seen that Perfect Fitness with the highest water absorption capacity could provide a prolonged cooling effect than other three products since the cooling is activated by the water absorbed in the fabric. The higher amount of water can allow more water evaporation for a longer period of time.

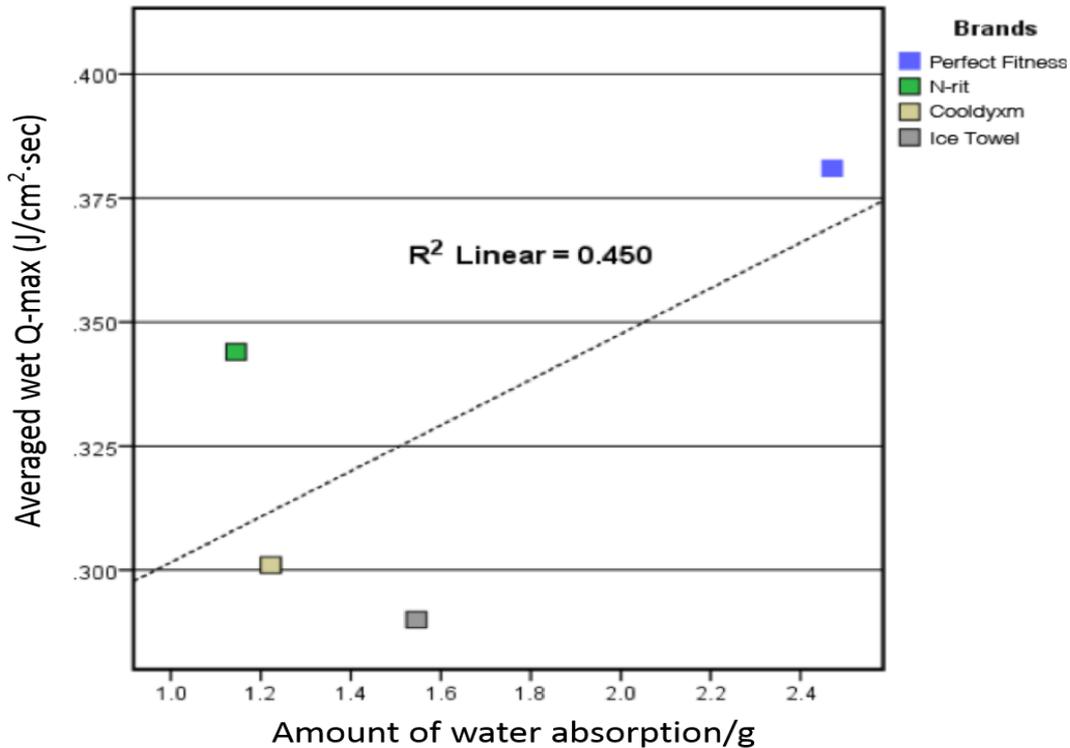


Figure 5. Relationship between water absorption and wet Q-max.

Relationship between Fabric Thickness and Wet Q-max

Selli and coworkers [5] indicated that fabrics with thinner outer layer would have higher coolness to touch. However, the correlation analysis showed that there is not significant correlation between fabric thickness and wet Q-max. From the correlation analysis (Table 5), as the p-value was 0.257 (> $\alpha = 0.05$), it is confident to show that fabric thickness and wet Q-max were not correlated. The coolness of wet fabrics was independent of fabric thickness.

Table 5. Correlation between fabric thickness and wet Q-max.

		Fabric thickness/mm
Averaged wet Q-max (J/cm ² ·sec)	Pearson correlation	0.743
	Sig. (2-tailed)	0.257

Figure 6 shows the linear relationship between fabric thickness and wet Q-max. Though the fabric of N-rit was the thinnest, the wet Q-max value was higher than that of Cooldyxm and Ice Towel, both of which were higher than that of N-rit. It still cannot conclude that the lower the thickness, the higher the wet Q-max as the thickest fabric of Perfect Fitness had the greatest instant coolness sensation. Although thick fabric could hold more water at its yarn interstice or fiber space when compared with thin fabric as the contact degree of water at yarn interstice is greater for thick fabric, the previous analysis shows that the wet Q-max was not correlated to the amount of water

absorbed by the fabric. Thus the correlation between fabric thickness and wet Q-max cannot be proved based on the SPSS analysis.

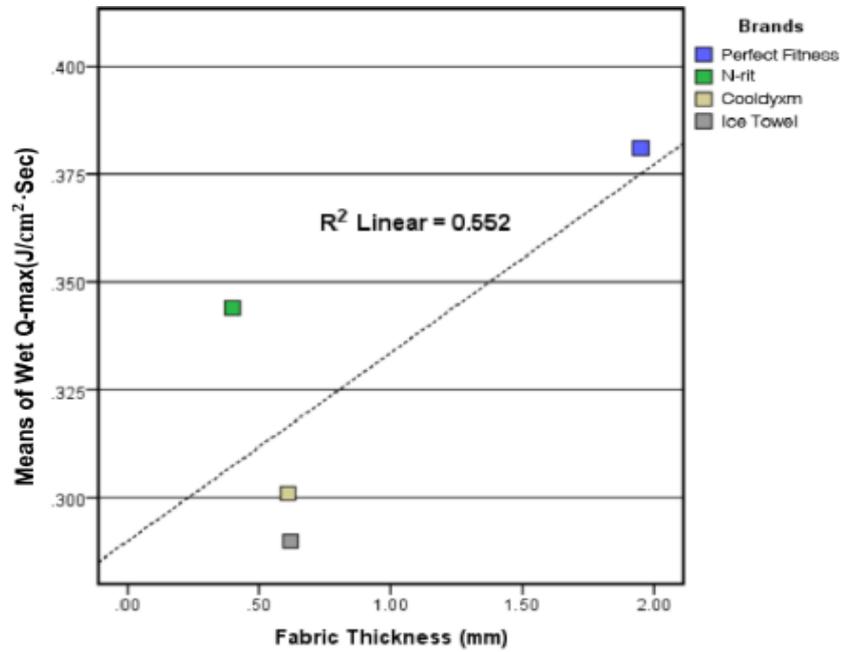


Figure 6. Relationship between fabric thickness and wet Q-max.

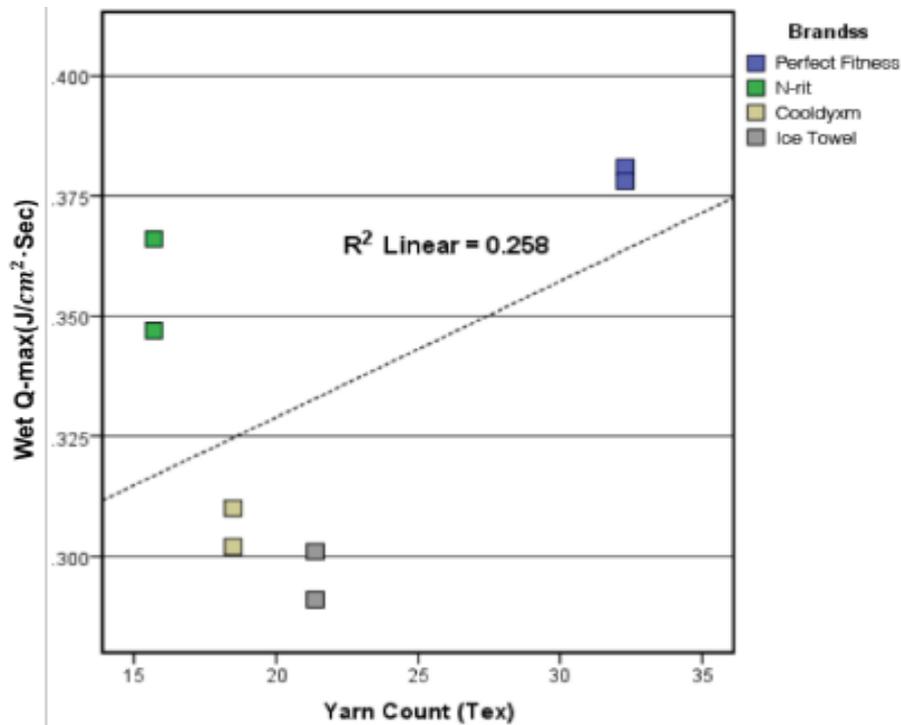


Figure 7. Relationship between yarn count and wet Q-max.

Relationship between yarn linear density and wet Q-max

Afzal et al. [6] found that an increase in yarn fineness would lead to a decrease in thermal absorptivity and the cool sensation. However, in this study, it was found that wet Q-max of the fabric was independent of the yarn count. From the correlation analysis (Table 6), as the r-value equaled to 0.508 and p-value was 0.199 ($>\alpha = 0.05$), thus there was no correlation between these two variables. As can be seen from the graph (Figure 7), yarn count may not be the factor affecting wet Q-max as Perfect Fitness of coarsest yarn and N-rit of finest yarn are the two products with the highest wet Q-max values, thus yarn count may not be the factor affecting the instant coolness sensation.

Table 6. Correlation between yarn count and wet Q-max.

		Yarn count/Tex
Averaged wet Q-max (J/cm ² ·sec)	Pearson correlation	0.508
	Sig. (2-tailed)	0.199

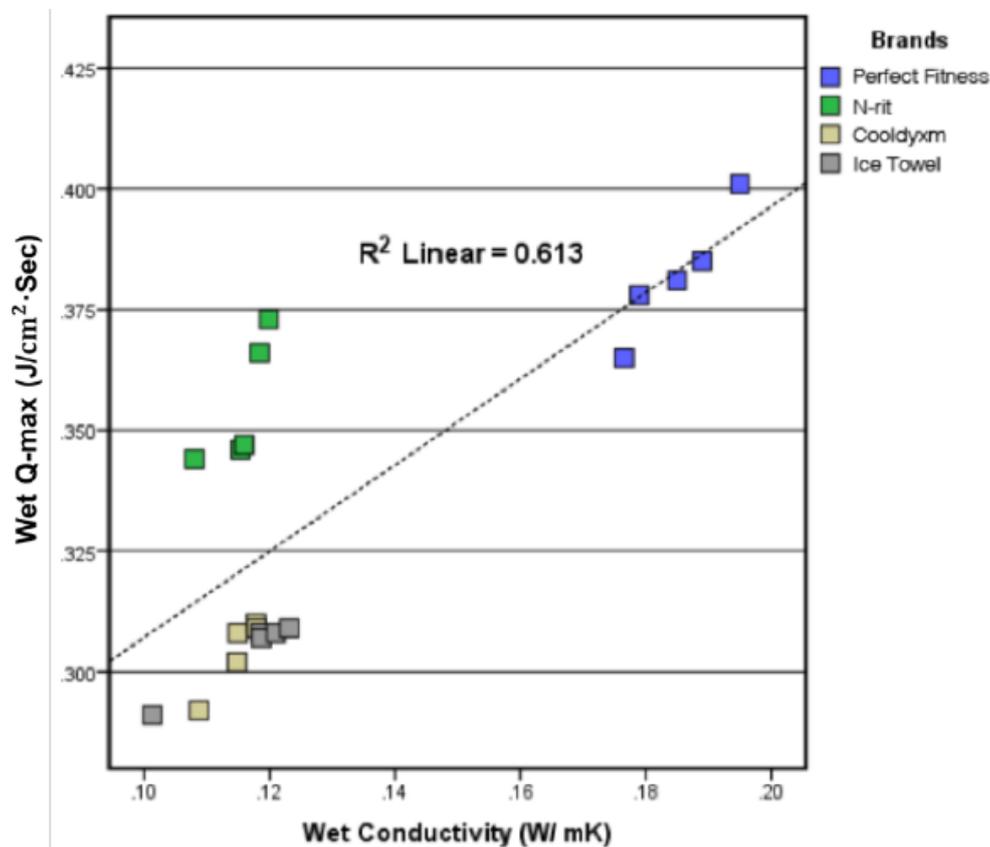


Figure 8. Relationship between thermal conductivity and wet Q-max.

Relationship between Thermal Conductivity and Q-max

Table 7 shows the correlation between thermal conductivity and Q-max. The p-value and the r-value were 0.000 ($<\alpha = 0.01$) and 0.783 ($r > 0.7$, strong correlation) respectively, it is confident to prove that these two variables were positively and strongly correlated. From Figure 8, the plot shows the positive and linear relationship between thermal conductivity and Q-max. It can be seen that fabrics with higher thermal conductivity value would also have better Q-max performance and greater instant coolness of sensation, vice versa. Sample of Perfect Fitness has

highest thermal conductivity and Q-max as well, which interprets that fabric with greater heat transfer ability and rapid rate of heat flow through the fabric would tend to have a feeling of coolness and higher Q-max value.

Table 7. Correlation between thermal conductivity and wet Q-max.

	Wet thermal conductivity(W/mK)
Averaged wet Q-max (J/cm ² ·sec) Pearson correlation	0.783
Sig. (2-tailed)	0.000

One-way ANOVA analysis on wet Q-max values between the samples

From one-way ANOVA analysis (Table 8), as p-values was 0.000 (< $\alpha = 0.05$), and the difference of mean of wet Q-max among Perfect Fitness, N-rit, Cooldyxm and Ice Towel was statistically significant at $\alpha = 0.05$.

Table 8. One-way ANOVA of means of wet Q-max.

	Sum of squares	df	Mean square	F	Sig.
Between groups	0.022	3	0.007	64.771	0.000
Within groups	0.002	16	0.000		
Total	0.024	19			

Table 9. Multiple comparisons of means of wet Q-max.

(I) Brands	(J) Brands	Mean difference (I-J)	Std. Error	Sig.
Perfect fitness	N-rit	0.0268	0.00679	0.006
	Cooldyxm	0.0778	0.00679	0.000
	Ice Towel	0.0774	0.00679	0.000
N-rit	Perfect Fitness	-0.0268	0.00679	0.006
	Cooldyxm	0.0510	0.00679	0.000
	Ice Towel	0.0506	0.00679	0.000
Cooldyxm	Perfect Fitness	-0.0778	0.00679	0.000
	N-rit	-0.0510	0.00679	0.000
	Ice Towel	-0.0004	0.00679	1.000
Ice Towel	Perfect Fitness	-0.0774	0.00679	0.000
	N-rit	-0.0506	0.00679	0.000
	Cooldyxm	0.0004	0.00679	1.000

From the post-hoc comparison of Tukey HSD (Table 9), it shows that there was significant mean difference of wet Q-max of Perfect Fitness with N-rit (p-value =0.006), Cooldyxm (p-value =0.000) and Ice Towel (p-value =0.000) as the p-values were lower than $\alpha = 0.05$. Also, N-rit was found to have significant mean difference of wet Q-max with Cooldyxm (p-value =0.000) and Ice Towel (p-value =0.000) as the p-values were lower than $\alpha = 0.05$ while the mean difference of wet Q-max was not statistically significant for Cooldyxm and Ice Towel (p-value =1.000) as the p-value was larger than $\alpha = 0.05$. Therefore, in term of wet Q-max, Perfect Fitness was statistically greater than N-rit, Cooldyxm and Ice Towel at $\alpha = 0.05$ while the difference between Cooldyxm and Ice Towel was not significant, they have the same mean wet Q-max property.

CONCLUSIONS

In this study, the cooling properties of summer cooling towels of different brands available in Hong Kong market were evaluated by Q-max analysis. It was found that all the samples could provide a cooling effect at first contact after being wetted. The samples of Perfect Fitness showed the highest cooling effect followed by the N-rit samples, whereas Street samples had the poorest cooling effect. The reason may be explained by the yarn density, fabric structure and thickness.

REFERENCES

- [1] Hong Kong Trade Development (2017). Council clothing industry in Hong Kong. Retrieved from <http://hong-kong-economy-research.hktdc.com/businessnews/article/Hong-Kong-Industry-Profiles/Clothing-Industry-in-Hong-Kong/hkip/en/1/1X47J8XF/1X003DCL.htm>.
- [2] Ezshopex (2017). Ending cooling towel. Retrieved from <http://ezshopex.com/endura-cooling-towel.html>
- [3] Hes, L., and de Araujo, M. (2010). Simulation of the effect of air gaps between the skin and a wet fabric on resulting cooling flow. *Textile Research Journal*, 80(14), 1488-1497.
- [4] Reischl, U., and Goonetilleke, R. S. (2016). Fabric Cooling by Water Evaporation. *Journal of Fiber Bioengineering and Informatics*, 9(4), 237-245.
- [5] Selli, F., and Turhan, Y. (2017). Investigation of air permeability and moisture management properties of the commercial single jersey and rib knitted fabrics. *Textile and Apparel*, 27(1), 27-31.
- [6] Afzal, A., Ahmad, S., Rasheed, A., Ahmad, F., Iftikhar, F., and Nawab, Y. (2017). Influence of fabric parameters on thermal comfort performance of double layer knitted interlock fabrics. *Autex Research Journal*, 17(1), 20-26.