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Evaluation of Kinetic Performance for Men's Suit Jacket in Exercise of Shoulder Joint

***Hiroyuki KANAI*[*1], *Hajime TSUJI*[*2], *Masayoshi Kamijo*[*1], *Yo-ichi MATSUMOTO*[*1],
Toyonori Nishimatsu[*1] , *and Kiyohiro Shibata*[*3]

[*1] Faculty of Textile Science and Technology, Shinshu University,
3-15-1 Tokida, Ueda, Nagano 386-8567, Japan
[*2] Graduate school of Shinshu University,3-15-1 Tokida, Ueda, Nagano 386-8567, Japan
[*3] Aoki Holdings, 60-1 Meichi aza Shimoyanaginouchi, Ichinomiya, Aichi 494-0012,Japan

Abstract: This paper describes the kinetic performance evaluation of suit jacket by measurement of clothing pressure. Subjects wearing three suit jacket of different size performed three different exercises involving the rotation of the upper limbs. The clothing pressure was measured by the air-pack sensor and the partial compression feeling and the constrained feeling were evaluated by subjects. From the result, it was found that (1) the partial compression feeling was correlated with the clothing pressure at the arm, the front of armhole and the scapula, (2) the Weber-Fechner's law was applicable to the relation between the clothing pressure and the compressive feeling, (3) The clothing pressure value which gave the low and moderate compression feeling to subjects was 1.2kPa and 3.6kPa, (4) the partial compression feeling at the arm, the front and back of armhole and the scapula was correlated with constrained feeling. Therefore the clothing pressure at the arm, the front of armhole and the scapula was the available index to evaluate the kinetic performance of suit jacket.

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1. Introduction

Generally speaking, to adapt the suit jacket for complex body shape and to keep a beautiful silhouette, 16-17 parts of fabrics are used for design of men's suit jacket, (e.g., front and back part of fabric, sleeve fabric, shoulder pad, lapel et. al.). And several darts are set on a design pattern of suit jacket and easing works are given in the sewing process. That is to say, the most important factor for a high product performance of the suit is the adaptability to human body in a static upright posture for designer.

On the other hand, skilled tailors consider their kinetic performance in manufacturing order-made suits for individuals. But it became difficult to provide a tailor-made suit in the mass production. However, with the recent change of marketing style from the mass production / consumption to the multi kind production as semi-order made style, the improvement of kinetic performance is strongly required.

A garment with bad kinetic performance inhibits certain movement because of the large forces at work on the human body in the opposite direction of the movement.

The forces working on the body are mainly equal to the clothing pressure. Therefore many researchers have investigated the measurement technique of clothing pressure and have developed several sensors [1-2].

Using these sensors, clothing pressure with many kinds of garment (e.g., waist belt, slacks, girdle, pantyhose brassiere, and socks) has been measured [3-8], but a few studies have reported for men's suit jacket [9].

Most of these studies have same point of view which is finding the measurement point where high pressure works, and investigate the relationship between the clothing pressure and subjective compressive feeling (e.g., harmful, acceptable and comfortable).

From these results, the relationship between the clothing pressure and compressive feeling is much influenced by the kind of garments (i.e., difference of wearing purpose, material, pattern and posture) even at same point of the body.

Therefore in this study, we investigated the available measurement points of clothing pressure for assessing the difference of suit jacket size. Furthermore, the subjective compressive feeling was evaluated at the same points, and discussed the correlation among the clothing pressure, the partial compressive feeling and the constrained feeling of the suit jacket in test exercising.

2. Experimental

2.1 Samples

Three different physiques of suit jacket (92Y5, 92A5, 92AB5) prescribed by JIS L4004 [10] was pre produced as experimental samples. The physique indication of suit jacket on JIS shows the adaptive size of the consumer's body. The first value shows the dimension of chest girth (e.g., '92' = 92cm), the next alphabet shows the difference between dimension of chest girth and that of waist girth (e.g., 'Y'=16cm, 'A'=12cm, 'AB'=10cm), and the last value shows the height (e.g., '5'=170cm).

Figure 1 shows the positions of chest girth (CG), waist girths (WG), jacket height (JH), armhole (AH), sleeve length (SL), and its additional dimensions from 92Y5 jacket. For example, the chest girth of 92A5 jacket was 2cm larger and 92AB5 jacket was 6cm larger than 92Y5 jacket. The height of 92Y5 jacket was as high as 92A5 and 92AB5 jacket. That is to say, all dimensions of Length direction were same, but the all dimensions of width direction and girths were similar on the three suit jackets.

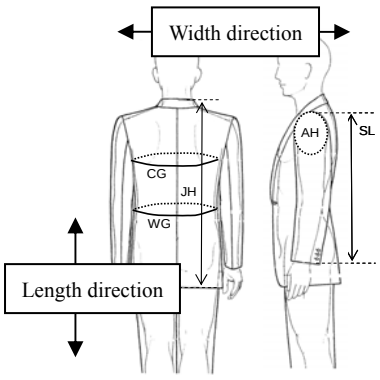
In comparing the weight of the three suit jackets, the 92Y5, the 92A5, the 92AB5 jackets were 729g, 741g, and 752g.

The weave pattern of the suits was twill. The weight of wool fabric for suit is 229gf/m^2. The warp yarn density was 85.7ends/inch and the weft yarn density was 71.6picks/inch.

2. 2 Subjects

The body dimensions of ten Japanese male subjects enrolled in textile courses at Shinshu University were measured using the Martin technique [11].

The average height was 170.7cm, the average weight was 66.0kg, and the average Body Mass Index (BMI) calculated as body weight divided by height squared was 22.6kg/m^2. The World Health Organization (WHO) defines BMI 20-25kg/m^2 as the normal weight. Ten subjects were suit for 92A5 physique. The average age of the subjects was 23 years.



unit (cm)

dimension	92Y5	92A5	92AB5
JH	0	0	0
SL	0	0	0
CG	0	+2	+4
WG	0	+4	+10
AH	0	+0.8	+2

Fig. 1 Dimensions of suit jackets.

2.3 Experimental exercise

In the case of a wearing test for assessing the restraint of suit jacket, it is necessary to prescribe the experimental exercise, because the complex movements which are observed in daily life are not reproducible.

The requirement factors of the experimental exercise were as follows.

(1) To simplify the interpretation of data, the exercise which is carried out by a work of mono-joint should be selected.

(2) To evaluate the restraint of suit jacket easily for subjects, the exercise by which the large deformation of jacket fabric is occurred should be selected.

(3) The exercise which is an elemental motion of daily movement should be selected

From these requirements, we aimed to an exercise of shoulder joint which had large movable area. According to the rotation of upper limbs, it was predicted that a sleeve fabric was largely deformed with front and back part of suit jacket. That is to say, it is predicted that the kinetic performance of suit jacket influences on not only the part of upper limbs but also the trunk part of subjects.

Therefore in this study, the rotations of upper limbs on three different planes (i.e., the anterior elevation on sagittal plane, the abduction on frontal plane and the adduction on horizontal plane) were prescribed as the experimental exercise shown in Fig.2.

These exercises are an elemental motion of daily movement (e.g., to straphang in bus or train, on steering of a car).

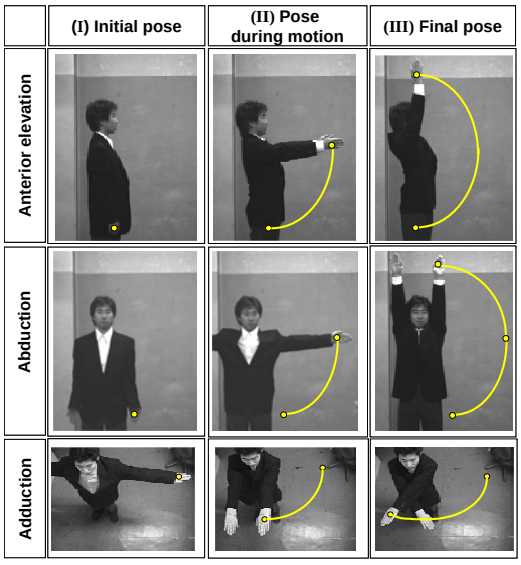


Fig. 2 Experimental exercise of shoulder joint.

The anterior elevation exercise was as follows: Subject stood in front of the camera (I), raised his upper limbs along the sagittal plane (II), and kept his arms raised over his head for a few seconds (III).

The abduction exercise was as follows: Subject stood in front of the camera (I), his upper limbs were abducted along the frontal plane (II), and he kept his arms raised over his head for a few seconds (III).

The adduction exercise was as follows: Subject stood under the camera and raised his arms to the shoulder line (I), then adducted his upper limbs along the horizontal plane (II), and kept his arms crossed for a few seconds (III). Each subject wore the suit jacket over the same type of shirt and slacks.

2.4 Measurement of clothing pressure

The clothing pressure working on the body is caused by linkage of partial tensile strain on fabric. If the fabric has enough ability of stretching to certain motion, this partial tensile strain is not occurred as the body skin. There are countless small wrinkles on the skin around the shoulder joint (See Fig3-(a)). According to the rotation of upper limbs, these wrinkles are expanded and do not prevent motions [12].

In the Figure 3-(a) arrows were drawn by linkage of the normal to the each wrinkle. Therefore it is predicted that the direction of arrows agreed with the direction of the partial tensile strain of suit jacket fabric occurred in the case of anterior elevation (see Fig.3-(b)). Therefore it was predicted that the points where were the end of the arrows (i.e., front and back of armhole, arm and scapula) is pressed highly by the tensile strain of fabric. In addition to these points, the neck and the acromion where support the weight of the suit jacket in a static upright posture was selected as measurement point of clothing pressure as shown in Fig.4.

The measurement points at where high clothing pressure worked during experimental exercise were investigated in the previous experiment. The clothing pressure at p1-p5 in final pose of anterior elevation was shown in Table 1. From the result, the p2 was decided as the measurement point of the arm, because the highest clothing pressure was worked on every subject. Also the other points were decided with the same way.

Air-pack sensors (20φ in diameter, AMI3037, AMI Co. Ltd.) were put on the six points of right half body for measurement of the clothing pressure between the jacket and the body. The maximum thickness of the sensor was 1mm and the sampling frequency was 1Hz.

The clothing pressure was measured in static condition for three seconds. The measurement postures were initial

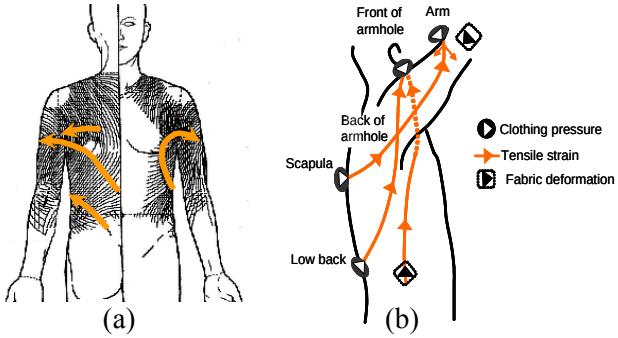
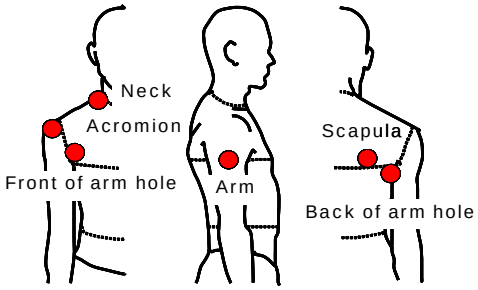


Fig.3 Wrinkles of skin around the shoulder joint. [12] (a) Wrinkle pattern of the skin around the shoulder joint. (b) Tensile strain model base on the wrinkle pattern of skin.



(a) Front view (b) Side view (c) Back view

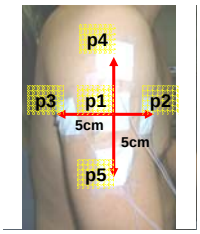
Fig. 4 Measurement points for clothing pressure and sensory evaluation.

Table 1 Investigation of measurement points for clothing pressure at arm.

(kPa)

	p1	p2	p3	p4	p5
Subject 1	2.9	4.5	1.5	1.3	0.0
Subject 2	3.1	3.1	1.8	0.3	0.1
Subject 3	2.2	2.5	1.1	0.2	0.3
Subject 4	1.4	2.0	0.8	0.5	0.9
Subject 5	0.8	1.6	1.6	0.5	0.1

∗ The highest clothing pressure



pose (I), the pose during the exercise when the rotation angle of the upper limbs was ninety degrees (II) and the final pose (III) shown in Fig. 2 (posture of (I), (II)and (III) for the anterior elevation and the abduction, and (I) and (III) for the adduction). Each subject performed three times per a sample which was randomized and the average of pressures was calculated at each point.

2.5 Sensory evaluation

Sensory test was carried out in different protocol with the measurement of clothing pressure.

To investigate the subjective compression feeling that a jacket imposed on the body and the feeling of constraint that a jacket inhibits the experimental exercises, descriptive words such as “feel pressure” and “feel hard (or easy) to move the upper limbs” were judged using the Semantic Differential (SD) method.

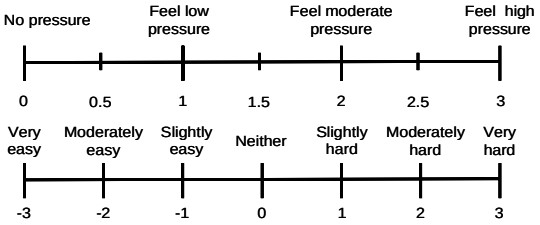


Fig. 5 Score scale of sensory evaluation.

The partial compression feeling at the six points as shown in Fig. 4 was judged on seven scale in Fig.5

(i.e.,0pt: "no pressure", 0.5pt: between "no pressure" to "feel low pressure", 1pt: "feel low pressure", 1.5pt: between "feel low pressure" to "feel moderate pressure", 2pt: "feel moderate pressure", 2.5pt: between "feel moderate pressure" to "feel high pressure", 3pt: "feel high pressure"). The constrained feeling caused by the suit jacket was evaluated on a seven-point scale in Fig. 5 (i.e., -3pt: very easy, -2pt: moderately easy, -1pt: slightly easy, 0pt: neither, 1pt: slightly hard, 2pt: moderately hard, 3pt: very hard).

After the subjects exercised each motion for three times, they evaluated the score scales by themselves as shown in Fig.5. The order of samples and exercises were randomized. Only one sample was evaluated in one day, because the evaluation should be carried out in SD method (i.e., absolute evaluation).

The experimental room was maintained at 23ºC, and 50% R.H..

3. Results and discussion

3.1 Clothing pressure

Figure 6 shows the average of clothing pressure at each point and posture on the result of 92A5 jacket. And Fig. 7 shows the tensile strain of 92A5 suit jacket fabric on the final pose of exercise**.**

The wrinkles were occurred by tensile strain when subjects raised their upper limbs. It was found that the direction of wrinkles adapted to the direction of arrows drawn in Fig.3-(b) on anterior elevation.

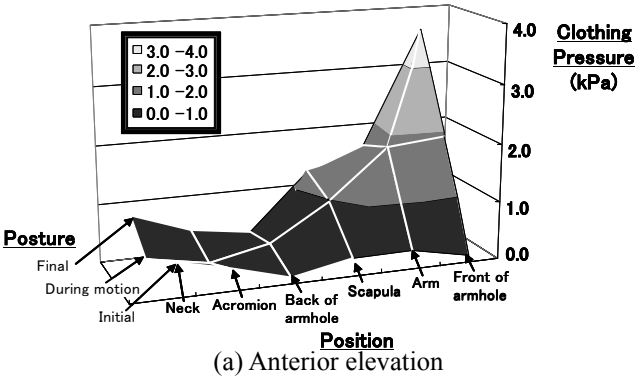
In the case of the anterior elevation (Fig. 6-(a)), the pressures of the initial pose were under 1.0kPa at every point. But the pressure during motion and that of the final posture, the pressure was increased over 1.0kPa at the scapula, the arm, and the front of armhole.

In the case of the abduction and adduction (see Fig. 6-(b), (c)), the pressures of the initial pose were also under 1.0kPa at every point. The pressure increased at the arm and the front of armhole in abduction, and at the front and back of armhole, the scapula, and the arm in adduction on the final posture.

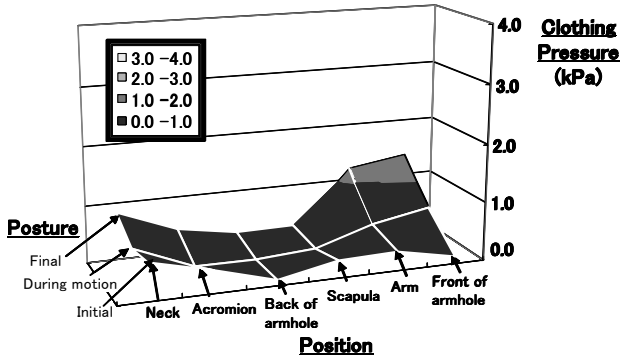
As the pressure at the anterior elevation was highest, therefore it was supposed that the largest constrained was felt when subjects exercised the anterior elevation.

It was also supposed that the notable measurement points of clothing pressure for assessing the kinetic performance of suit jacket were the front of armhole, the arm, and the scapula. In comparing three suit jackets at these points, the clothing pressure of 92Y5 jacket was the highest.

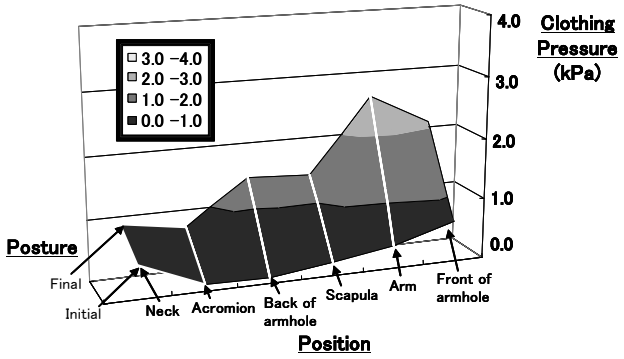
In particular, the clothing pressure level at the front of armhole was over 4.3kPa as indicated by the broken lines (Fig.8). This pressure level corresponds with the inside pressure of the capillaries [13] and influences human health greatly.



(a) Anterior elevation

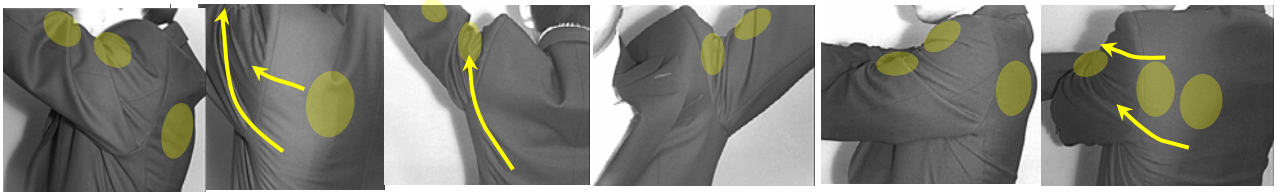


(b) Abduction



(c) Adduction

Fig.6 Result of clothing pressure.



(a) Anterior elevation (b) Abduction (c) Adduction

Fig.7 Tensile strain of fabric in the experimental exercises.

Table 2 Mean rating score on partial compression feeling and constrained feeling.

Motion	Anterior elevation			Abduction			Adduction		
Size	92Y5	92A5	92AB5	92Y5	92A5	92AB5	92Y5	92A5	92AB5
Neck	0.3	0.6	0.2	0.3	0.3	0.1	0.4	0.4	0.2
Acromion	0.7	0.5	0.6	0.6	0.3	0.4	0.8	0.6	0.4
Arm	2.2	2.0	1.8	0.9	0.7	0.6	2.2	1.8	1.5
Front part of armhole	2.4	2.1	1.7	0.6	0.9	0.5	1.5	1.5	0.8
Back part of armhole	1.7	1.0	1.2	0.4	0.3	0.4	1.3	1.0	0.6
Scapula	1.6	1.1	1.1	0.3	0.2	0.1	1.5	1.1	1.0
Constrained feeling	1.8	0.5	0.4	−0.8	−1.5	−1.7	0.6	0.1	−0.9

3.2 Constrained feeling of suit jacket

Table 2 shows the mean rating scores of the partial compression feeling at each point and the constrained feeling in three motions.

In comparing three suit jackets, subject wearing 92Y5 jacket felt the strongest constraint in all exercises.

Therefore, subjects felt the difference of clothing pressure which was influenced by the physiques among 92Y5, 92A5 and 92AB5 jacket.

The mean rating scores of constrained feeling were all negative in the abduction, but all positive in the anterior elevation. From the result in the adduction, the mean rating score of constrained feeling was in a range between -1 (i.e., slightly easy) and 1 (i.e., slightly hard). That is to say, subjects felt it easy to do the abduction exercise and not hard to do the adduction but hard to do the anterior elevation, because of the constraint of suit jackets. This result agreed with the result of clothing pressure.

From the result of the mean rating score of partial compression feeling in 92A5 jacket, subjects felt the moderate compression at the front of armhole and the arm, and felt low compression at the scapula and the back of armhole. However, they did not feel compression even slightly at the neck and the acromion when they raised their upper limbs in the anterior elevation.

3.3 Relation between clothing pressure and subjective feelings

The correlation between the clothing pressure and the partial compression feeling at each measurement point was analyzed using the nine sets of data (3 suit jackets and 3 exercises) by the correlation analysis.

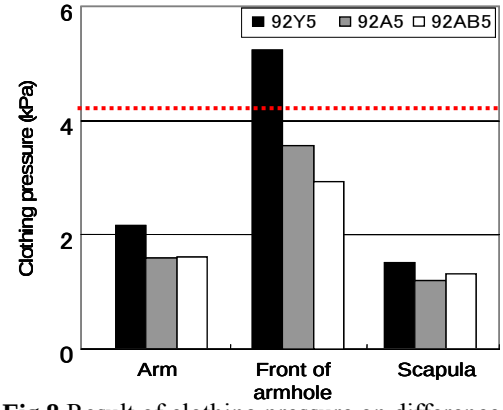


Fig.8 Result of clothing pressure on difference of physiques.

From the result of correlation analysis, there were a positive correlation between the clothing pressure and the partial compression feeling at the arm ($r=0.77$, $p<0.05$, $\alpha=0.65$), the front of armhole ($r=0.88$, $p<0.01$, $\alpha=0.48$), and the scapula ($r=0.96$, $p<0.01$, $\alpha=1.05$).

As the clothing pressure decreased, the slope of regression line (α) became large. When the compression feeling was presumed as the response to the stimulus, the Weber- Fechner's low ($E = K \log R+C$, $K=0.90$, $C=0.83$) was applicable to the relation between the clothing pressure and compression feeling as shown in Figure 9. The constant C shows the threshold of compression feeling to the clothing pressure. Namely, the partial compression feeling depended on clothing pressure value rather than the body part where clothing pressure worked.

The clothing pressure value which gives the low and moderate compression feeling to subjects was estimated 1.2kPa and 3.6kPa from the regression equation of

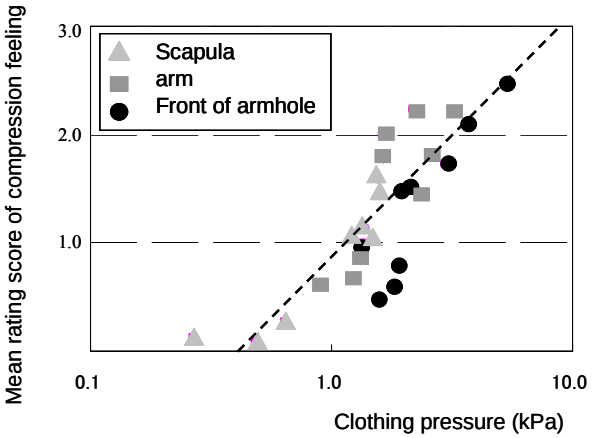


Fig.9 Relation between clothing pressure and mean rating score of partial compression feeling

Weber-Fechner's law.

From the results of the correlation analysis, there was a positive correlation between the mean rating scores of the compression feeling at the front($r=0.94$, $p<0.01$) and back($r=0.95$, $p<0.01$) of armhole, the arm($r=0.87$, $p<0.01$), the scapula($r=0.83$, $p<0.01$) and the constrained feeling. Therefore the partial compression feeling was strongly related with the constrained feeling of suit jacket.

That is to say, it was found that the partial compression feeling was the main factor of constrained feeling of suit jacket. And the clothing pressure at the arm, the front of armhole and the scapula was the available evaluation index to evaluate the kinetic performance of a suit jacket.

4. Conclusion

In this study, we investigated the available measurement point for assessing the difference of kinetic performance among the 92Y5, 92A5 and 92AB5 jackets during the three kind of exercise on shoulder joint. Furthermore, the relationship among the clothing pressure, subjective compression feeling and constrained feeling was investigated. The results are summarized as follows:

(1) Consideration for the influence of kinetic performance of suit jacket on three experimental exercises, the restraint on the anterior elevation is stronger than that on the abduction and adduction.

(2) The front of armhole, the arm and the scapula are compressed strongly by suit jacket. And the subjects feel strong compression at these points because the tensile strain of the suit jacket fabric agrees with expanding direction of the skin.

(3) The Weber- Fechner's law ($E = K \log R$) is applicable to the relation between the clothing pressure and compression feeling. Furthermore, the clothing pressure value which gives the low and moderate compression feeling to subjects is 1.2kPa and 3.6kPa on the experimental samples.

(4) It is found that the partial compression feeling is strongly related with the constrained feeling. Therefore the measurement of clothing pressure is available for evaluation of kinetic performance of suit jacket.

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