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Upper Body Surface Change Analysis using 3-D Body Scanner

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3차원 인체 측정기를 이용한 체표변화 분석

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Abstract

Three-dimensional(3-D) body scanners used to capture anthropometric measurements are now becoming a common research tool for apparel. This study had two goals, to test the accuracy and reliability of 3-D measurements of dynamic postures, and to analyze the change in upper body surface measurements between the standard anthropometric position and various dynamic positions. A comparison of body surface measurements using two different measuring methods, 3-D scan measurements using virtual tools on the computer screen and traditional manual measurements for a standard anthropometric posture and for a posture with shoulder flexion were -2~20mm. Girth items showed some disagreement of values between the two methods. None of the measurements were significantly different except for the neckbase girth for any of the measuring methods or postures. Scan measurements of the upper body items showed significant linear surface change in the dynamic postures. Shoulder length, interscye front and back, and biacromion length were the items most affected in the dynamic postures. Changes of linear body surface were very similar for the two measuring methods within the same posture. The repeatability of data taken from the 3-D scans using virtual tools showed satisfactory results. Three times repeated scan measurements for the scapula protraction and scapula elevation posture were proven to be statistically the same for all measurement items. Measurements from automatic measuring software that measured the 3-D scan with no manual intervention were compared with the measurements using virtual tools. Many measurements from the automatic program were larger and showed quite different values.

Key words: 3-D body scanner, Body surface change, Reliability, Dynamic postures; 3차원 인체 측정기, 체표변화, 신뢰도, 동적 자세

I. Introduction

Anthropometric database are of great importance for sizing system of clothing and the work environment. The development of existing technology makes it possible to collect anthropometric data using a non-contact body scanner. This technology eliminates the greatest hindrances to anthropometric surveys. It's time and data reproducibility(Mckinnon, Istook, 2002). Scanning technology has been around

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for over 30 years. Only recently this technology has been used in human anthropometric applications. Three-dimensional scanning offers a technique to capture the body dimensions in a fast and reproducible way(Yu et al., 2003). This technology also offers rapid response, reduced overhead costs, and can contribute to better fitting garments. The body scanning process consists of a series of computer photographs, which are captured using various techniques. The images extracted are useless, however, without well developed data extraction software.

Reliability and repeatability have been important issues in the development of 3-D anthropometrics. Bougourd et al.(2000) reported the reliability and repeatability of 3-D whole body scanning measurements and anthropometry for the standard anthropometric position. But there has been little published literature on the measurements of 3-D anthropometric approaches for active postures. Dynamic anthropometric data can be useful for many ergonomic studies, for sizing and fit of functional apparel, and other product designs.

The objectives of this study were to verify the reliability of 3-D body scan measures for dynamic postures. Body surface length and girth changes produced by upper body and arm movements were measured and compared using traditional anthropometry and 3-D scan technology. There were four main objectives for this study. The first was to compare traditional anthropometric measurements with 3-D body scan measures of standard anthropometric and dynamic posture, in order to verify the accuracy of 3-D body scan measures. The second, to provide linear upper body surface change ratio measurements of the dynamic postures needed for functional clothing, and to compare the change ratio deriving using the two measuring methods. The third, to investigate the reliability of repeated 3-D scan measures. The fourth, to compare measurements extracted by a completely automated body measurement process with measurements taken using interactive virtual measurement tools to derive the measurements.

II. Background

1. Anthropometric Accuracy: Reliability and Repeatability

3-D body scanning technology is useful tool not only for anthropometric measurement but also a promising tool for the apparel industry for custom-fit garment production. Reliability(i.e. valid measurements that are useful for the apparel industry) and repeatability(i.e. the same measurements generated with each repeated test) have been important issues in 3-D anthropometrics. Park and Nam(2004) studied the optimal postures and positioning or accuracy problem for human body scanning. In a study of accuracy of 3-D anthropometry, Daanen et al.(1997) reported that a pointer stabilizing the head reduced the magnitude of sway by 50%. Respiration variables during the scan determine the shape of the chest and

Table 1. Research on the accuracy of 3-D anthropometry

Author	Purpose	Key points
Park et al.(2004)	Standardization of 3-D body scanning	Calibration
Yu et al.(2003)	Body surface area calculation	Calibration
Mckinnon et al.(2002)	Effects of subject respiration and foot positioning	Respiration, Foot positioning
Brunsman et al.(1997)	Optimal posture and positioning for human body scanning	Positioning
Dannen et al.(1997)	Reducing movements artifacts in whole body scanning	Breathing, Sway

Table 2. Research on the reliability of 3-D anthropometry

Author	Purpose	Key points
Feathers et al.(2004)	Measurement consistency and 3-D electromechanical anthropometry	Consistency
Bougourd et al.(2000)	Comparison of women's sizing by 3-D and traditional anthropometry	Reliability
Brooke et al.(1994)	Comparison of 3-D body scanner measurements with traditional anthropometry	Reliability

may have an effect on results. Foot placement also has a significant effect on measurements from body scan data. The accuracy of body surface measurements using a properly calibrated 3-D scanner are generally believed to be better than traditional direct measurements and indirect estimation if scan variables are properly controlled(Table 1).

On the reliability of 3-D anthropometry, Feathers et al.(2004) said there were some small systematic differences in measurements made between conventional and electromechanical methods. The reliability of the electromechanical method was comparable to, but not better than the conventional method. But Bougourd et al.(2000) and Brooke et al.(1994) reported that measurements by 3-D scanning and traditional anthropometry were generally similar on many key items(Table 2).

Compared to traditional anthropometry, The disadvantages of 3-D scanning include investment in the scanner, missing data because of shading(for example, the arm-pits and crotch areas are often shaded) and possible occurrence of errors owing to body movement. Moreover, error may be introduced to the data through the lack of standardization that currently exists in the scanning process. Inhalation and exhalation are known factors that can affect critical measurements in the torso(Brunsman et al., 1997). As has also been found in traditional anthropometric studies, there are many sources from which measurement error may arise. Perhaps the easiest to quantify are instrument precision and accuracy. All other errors may be referred to as "observer error" resulting from inconsistent execution of measuring protocol. These errors include imprecision of landmark location, subject positioning, and instrument application(Williamson et al., 1997).

2. Anthropometric Studies of Dynamic Postures

Garments that are worn in active working conditions must fulfill the demands of the working context. An investigation of body movements and garments found that the garment distortion appeared to be significantly related to the movements of the upper body, especially to the movements of the arms (Aldrich et al., 1998). Specially designed postures are generally used in movements studies for measuring the range of joint motion. These postures define isolated simple movements of a single joint without the confounding effects of multiple movements. Some of these standardized postures are rarely used by real people in their real activities, but they are useful for analysis of movement data.

Previous researches of 3-D scans of dynamic postures are rare. Until now postures for human body scanning were traditional standing or seated stances (Bougourd et al., 2000; Brunsman et al. 1997). But to make use of the body scanner more extensively, body postures in a real working context should be investigated. One research study investigated changes in measurements between seated and standing postures using 3-D scanning(Ashdown et al., 2004). Scans were analyzed to investigate the body measurements change and its application to pants fit. No studies using the 3-D body scanner to measure the dynamic postures for the upper body have been reported. <Table 3> shows research on the 3-D scans of other postures other than the standard anthropometric position.

III. Methods

1. Subjects and Anthropometry

Subjects were 25 females in their twenties, who

Table 3. Research on the 3-D scans of other postures

Author	Postures	Purpose
Ashdown et al.(2004)	Sitting position	Measuring the body measurements change and evaluate the fit
Bougourd et al.(2000)	One foot resting on a raised support, Knee bent at a right angle	Comparing the difference values between two methods
Brunsman et al.(1997)	Standard sitting, Coverage sitting	To maximize the surface area coverage, landmark visibility

wore garment sizes between 6~10 Misses in USA sizing. Subjects wore a lycra body suit<Fig. 1> during the scan process and the manual measurements.

Traditional anthropometric measures were measuring processes using a tape and an anthropometer. Electronic anthropometry was carried out using the VITUS whole body scanner and ScanWorX Body Measure and ScanWorX Tailor measuring software to extract data. ScanWorX BodyMeasure is a software that provides virtual measurement tools that can be applied to a scan that correspond to traditional anthropometry tools. These tools can be used to derive almost every conceivable measurement on the scan of the body. ScanWorX Tailor generates measurements from a scan automatically. In the first step, landmarks are extracted automatically based on the geometry of the body. Specific body dimensions are defined based on these landmarks, and appropriate measurement rules are then applied directly to the scan(Trieb et al., 2000). Each subject was scanned in the standard anthropometric position and three dynamic positions. The actual scanning process took 12 seconds, with about one minute processing time between scans.

2. Dynamic Postures and Measuring Items

Eighteen dimensions of the upper body were measured in three dynamic postures as well as the standard anthropometric posture(Table 4). The three dynamic postures were both shoulders flexed and arms extended in the frontal plane at an angle of 135°(P2), arms flexed and scapula protracted(P3), and shoulders elevated(P4). These postures were selected to represent actual activities of daily life. A digital goniometer was used to measure and maintain the reliability of the postures(Fig. 2, 3).

Flat landmarks for traditional anthropometry and dimensional landmarks for 3-D measuring were used to mark specific landmarks(Fig. 4). Eighteen dimen-

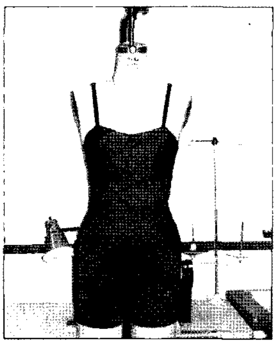


Fig. 1. Body Suit

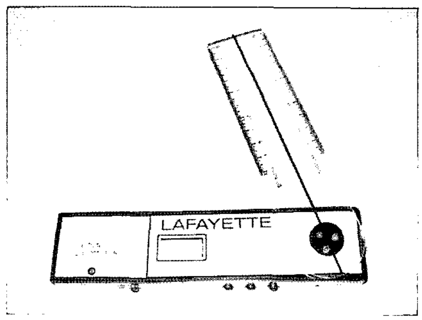
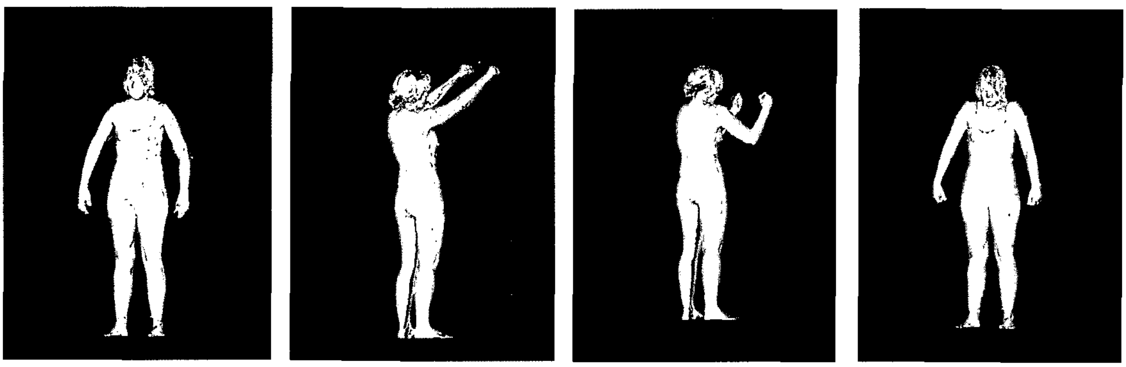


Fig. 3. Digital Goniometer



Standard Posture (P1) **Shoulder Flexion (P2)** **Scapula Protraction (P3)** **Scapula Elevation(P4)**

Fig. 2. Postures used in the study

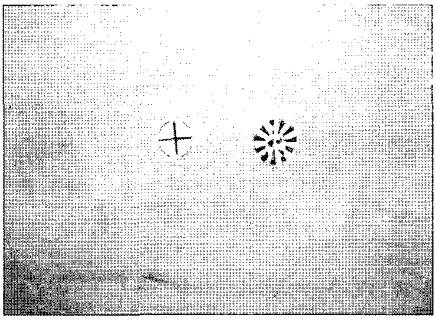


Fig. 4. Landmarks

sions of the upper body were measured using both traditional anthropometry and virtual measures of the 3-D scan for postures 1 and 2 while only virtual measures of the 3-D scans were done for postures 3 and 4.

3. Data Analysis

Descriptive statistics of traditional anthropometric and 3-D manual measures for all postures were analyzed to determine any differences between the measurements. Data analysis was done using SAS. Linear body surface change ratios among the different postures and identification of any significant differences between the measurement techniques were determined using a t-test. Multiple comparisons were made between the repeated measures to determine the reliability of 3-D scan measures for dynamic postures.

III. Results

1. Comparison of Traditional Anthropometric and 3-D Manual Scan Measurements

As indicated in Table 5, through the traditional anthropometric measurements, the average age, height and weight of the subjects were 21.8, 165.1cm, and 61.7kg respectively. The average Röhrer index was 1.37. Average bust and waist girth measurements were 88.3cm and 72.6cm. Measurements that exhibited a larger coefficient of variation were BP to BP, BP to waistline, and BP to underbust. Coefficient of variation(CV) is used to compare values with different units or with large mean differences. The larger CV values indicate that the items related to bust point reveal more individual differences among the subjects in upper body measurements related to the bust. Neckbase girth had the lowest coefficient of variation.

Using the ScanWorX Body Measure, this can calculate almost every conceivable dimension on the

Table 4. Measuring Items

Girths	Neckbase Girth	Bust Girth	Underbust Girth	Waist Girth
Lengths	Shoulder Length Neck Point to Bust Point(BP) BP to BP Scye Depth Scapula to Waistline		Interscye, Front BP to Underbust Biacromion Length Waist Back Length Sideline	Waist Front Length BP to Waistline Interscye, Back Neck Point to Scapula

Table 5. Descriptive statistics from traditional anthropometric measurements (Unit : mm, kg)

Items	Mean	Max.	Min.	CV	Items	Mean	Max.	Min.	CV
Neckbase Girth	377	396	350	2.4	Biacromion Length	385	410	330	5.2
Bust Girth	883	1010	812	5.2	Interscye, Back	345	378	302	6.0
Underbust Girth	768	900	682	5.8	Scye Depth	175	199	154	6.7
Waist Girth	726	873	650	6.7	Waist Back Length	382	402	328	4.0
Shoulder Length	122	130	110	4.4	NP to Scapula	233	260	210	5.6
Interscye, Front	319	354	300	4.0	Scapula to Waistline	187	204	158	5.6
Waist Front Length	325	359	295	4.7	Sideline	181	210	146	7.2
NP to BP	279	312	240	6.0	Height	1650	1780	1540	3.5
BP to Underbust	67	83	52	10.7	Weight	61.7	75.8	53.2	10.1
BP to Waistline	127	154	104	10.9	Age	21.8			
BP to BP	179	232	150	11.3	Rohrer Index	1.37			

human body. Scan measures showed difference value -2 to 18mm compared to the traditional measures at the standard posture. The scanned girth measurements were larger than the traditional measurements by 7~18mm. In case of shoulder flexion 135° posture, scanned girth measurements were larger than the traditional measurements by 7 to 20mm. In both postures, waist girth showed the largest difference between the two types of measurements. The mean girths derived from the manual scan measurements were all larger than the mean girths taken using traditional anthropometric methods. Mean length measurements were very close in value between the two systems, but generally across the body measures were a little larger and length measurements(along the body) were a little shorter in the scanned measurements. Previous research also found items related to body height and vertical length tended to be shorter or smaller when taken from 3-D data than the same measurement taken using standard anthropometric data(Lee et al., 2004). Analysis of the difference between the measurements taken for this study using a t-test revealed a significant difference in neckbase girth only($p\leq.01$) for both postures (Table 6).

2. Body Surface Change for Dynamic Postures

Examination of linear body surface changes that occur between the anthropometric position and dynamic postures using two measuring methods was the second objective of this study. Comparing the shoulder flexion position to the anthropometric position the sideline measurement increased about 20%, BP to underbust and interscye back increased about 10%. Bp to WL and, waist front length also increased

Table 6. Differences of -between two measuring methods for posture 1 and posture 2 (Unit : mm)

Items	S1		T1		S1-T1	t-value	S2		T2		S2-T2	t-value
	Mean	S.D.	Mean	S.D.			Mean	S.D.	Mean	S.D.		
Neckbase Girth	384	9	377	9	7	2.70**	376	10	369	9	7	2.43**
Bust Girth	901	46	883	46	18	1.32	890	42	875	44	16	1.33
Underbust Girth	780	43	768	45	12	0.97	785	41	770	44	14	1.20
Waist Girth	745	48	726	49	18	1.36	742	46	722	48	20	1.50
Shoulder Length	122	6	122	5	0	0.07	87	9	86	9	1	0.50
Interscye, Front	319	14	319	13	0	0.05	232	12	231	13	1	0.32
Waist Front Length	324	16	325	15	-1	-0.23	332	16	334	16	2	0.34
NP to BP	280	17	279	17	1	0.25	285	20	285	20	2	0.03
BP to Underbust	67	7	67	7	0	0.06	73	8	73	8	1	0.09
BP to Waistline	127	14	127	14	0	0.12	135	15	135	14	-1	-0.03
BP to BP	180	20	179	20	1	0.22	172	20	171	21	0	0.10
Biacromion Length	387	20	385	20	2	0.43	305	24	302	24	0	0.40
Interscye, Back	347	21	345	21	2	0.26	378	23	376	24	0	0.32
Scye Depth	173	12	175	12	-2	-0.39	171	11	172	12	-1	-0.25
Waist back Length	380	15	382	15	-2	-0.55	369	16	371	17	-2	-0.38
NP to Scapula	231	13	233	13	-2	-0.45	225	13	226	13	-1	-0.48
Scapula to Waistline	186	10	187	11	-1	-0.38	182	10	183	10	-1	-0.27
Sideline	180	13	181	13	-1	-0.20	217	17	218	16	-1	-0.24

**: $p\leq.01$
S1 : Scan Measures for Posture 1
T1 : Traditional Measures for Posture 1
S2 : Scan Measures for Posture 2
T2 : Traditional Measures for Posture 2

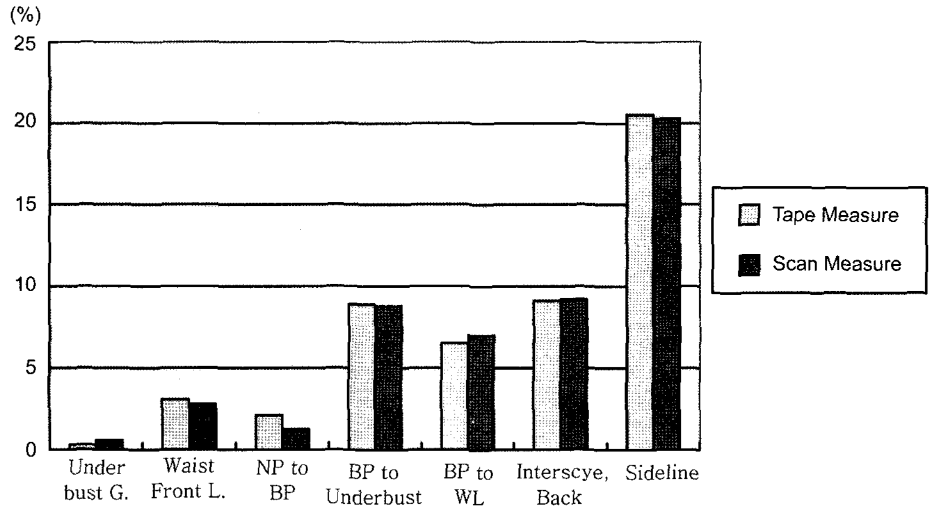


Fig. 5. Body surface increased item for posture 2

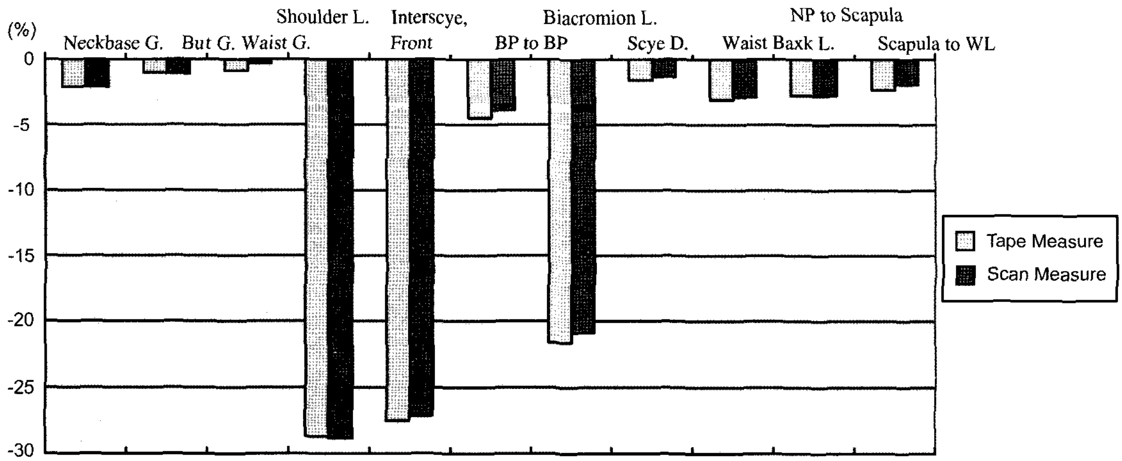


Fig. 6. Body surface decreased item for posture 2

a little. However many items decreased in the shoulder flexion posture. Shoulder length, interscye, and front decreased nearly 30%; biacromion length decreased over 20%. Other items decreased a small amount, generally under 5%.

Changes in linear body surface measurements between different positions were very similar for the two measuring methods. While 10 items were changed significantly in the shoulder flexion posture, 9 items derived by manually measuring the 3-D scan were changed significantly.

<Table 7> shows the values of the linear body surface changes between the anthropometric positions and posture 2. Items with significant differences when the shoulder is flexed were the same except for waist front length. The neckbase girth, bust girth, shoulder length, BP to underbust, interscye, back, and NP to scapula had almost the same variation ratio. <Fig. 5, 6> shows the items of body surface change that increased and decreased respectively as well as items that exhibited only small changes.

Calculations of the differences between the anthropometric position and the scapula protraction position showed large increases in interscye and back measurements. The scapula to waistline and sideline measurements also showed small increases. The

Table 7. Linear body surface change between posture 1 and posture 2 (Unit : mm)

Items	T1	T2	t-value	S1	S2	t-value
Neckbase Girth	377	369	-3.04*	384	376	-2.87**
Bust Girth	883	875	-0.69	901	890	-0.77
Underbust Girth	768	770	0.16	780	785	0.37
Waist Girth	726	722	-0.30	745	742	-0.21
Shoulder Length	122	86	-17.54***	122	87	-15.66***
Interscye, Front	319	231	-24.59***	319	232	-23.74***
Waist Front Length	325	334	2.14*	324	332	1.99
NP to BP	279	285	1.10	280	285	0.90
BP to Underbust	67	73	2.85**	67	73	2.93**
BP to Waistline	127	135	2.04*	127	135	2.18*
BP to BP	179	171	-1.38	180	172	-1.51
Biacromion Length	385	302	-13.31***	387	305	-13.20***
Interscye, Back	345	376	4.81***	347	378	4.98***
Scye Depth	175	172	-0.85	173	171	-0.72
Waist Back Length	382	371	-2.50*	380	369	-2.41*
NP to Scapula	233	225	-1.69	231	225	-1.76
Scapula to Waistline	187	183	-1.38	186	182	-1.30
Sideline	181	218	8.97***	180	217	8.50***

*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$

Table 8. Multiple comparisons of scan measurements (Unit : mm)

Items	S1	S2	S3	S4	F-value
Neckbase Girth	383.9 A	376.0 B	385.8 A	382.9 A	4.23**
Shoulder Length	122.1 A	96.9 B	110.9 A	103.9 A	102.50***
Interscye, Front	318.9 A	232.0 D	272.8 B	288.9 C	220.72***
Waist Front Length	323.7 A	332.6 A	310.5 B	327.2 A	8.35***
BP to Underbust	67.3 B	73.1 A	63.3 B	71.6 A	9.92***
BP to Waistline	126.7 B	135.5 A	121.7 B	135.1 A	5.88***
Biacromion Length	387.3 B	304.6 D	404.2 A	355.8 C	91.43***
Interscye, Back	346.8 C	378.0 B	406.1 A	327.9 D	64.16***
Scye Depth	173.4 AB	171.0 B	178.9 A	178.4 A	2.78*
Waist Back Length	379.8 A	369.2 B	387.6 A	386.6 A	6.76***
NP to Scapula	231.0 AB	224.6 BC	223.5 C	237.2 A	6.37***
Scapula to Waistline	185.8 B	182.2 B	199.3 A	197.7 A	14.20***
Sideline	180.3 C	216.8 A	188.8 C	202.6 B	27.35***

S1~S4 : Scan Measures for Posture 1~Posture 4
*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$, A,B,C,D means different group ($A \geq B \geq C \geq D$) by multiple comparisons, LSD

interscye front decreased by 13%. For all other items, the amount of change was very small.

In the case of the scapula elevation posture, shoulder length was the measurement that decreased the most. The interscye front also decreased about 10%. The sideline increased about 13%. Based on multiple comparisons among all postures, LSD, 13 items had significant differences, and interscye front showed the greatest change in the dynamic postures. Shoulder length, biacromion length, interscye back also exhibited large changes in the different postures (Table 8).

An understanding of the locations and values of body length increases that occur in different body positions are important in pattern making for clothing. The items that increase must be addressed as key areas to create functionality in working clothing. For the dynamic postures in this study, while the shoulder length and interscye front generally decreased, the side line and interscye back generally increased in the dynamic postures. The shoulder flexion posture and the scapula elevation posture exhibited similar variations, but the scapula protraction generated different results. <Fig. 7> represents scan measurements of various body surface change values for the dynamic postures.

3. Reliability of Repeated 3-D Scan Measures

To test the reliability of scanned data, measurements were repeated 3 times for postures 3 and 4, to verify whether repeatedly measured data were the same. Multiple comparisons, LSD showed that although the measures for scapula protraction posture varied, there were no significant differences in any of the items. Rounded values for the repeated measurements of interscye front were 272, 273, and 274mm and waist front lengths were 309, 311, and 311 mm. These differences are not statistically different. Repeat measures of posture 4 were even closer in value, and showed no statistical differences. This means that the body scanner can be usefully used for analysis of dynamic postures and the data are reliable for controlled scanning postures. <Table 9> shows the results of repeated scan measures for postures 3 and 4.

4. Comparison of ScanWorX Body Measure and Tailor Measurements

The final research objective was to compare results from the automated measuring software supported by ScanWorX program to measurements manually taken from the scan. ScanWorX Body Measure software

Table 9. Repeated scan measures for posture 3 and 4 (LSD) (Unit : mm)

Items	S3-1	S3-2	S3-3	F-value	S4-1	S4-2	S4-3	F-value
Neckbase Girth	385.6 A	385.7 A	386.1 A	0.02	383.3 A	382.8 A	382.7 A	0.02
Bust Girth	878.1 A	878.1 A	878.7 A	0.00	886.8 A	885.8 A	886.4 A	0.00
Underbust Girth	771.0 A	772.0 A	771.7 A	0.00	782.6 A	782.3 A	783.1 A	0.00
Waist Girth	746.4 A	747.8 A	747.4 A	0.01	748.5 A	748.3 A	749.2 A	0.00
Shoulder Length	110.6 A	111.2 A	110.9 A	0.07	103.9 A	103.9 A	103.9 A	0.00
Interscye, Front	271.7 A	273.1 A	273.5 A	0.24	288.8 A	289.1 A	288.9 A	0.00
Waist Front Length	309.4 A	310.9 A	311.2 A	0.08	327.2 A	327.0 A	327.4 A	0.00
NP to BP	276.7 A	277.0 A	277.2 A	0.01	286.4 A	285.9 A	285.8 A	0.01
BP to Underbust	62.8 A	63.4 A	63.7 A	0.14	71.0 A	72.0 A	71.9 A	0.11
BP to Waistline	121.1 A	121.8 A	122.3 A	0.04	135.4 A	135.5 A	134.3 A	0.07
BP to BP	172.3 A	172.5 A	171.5 A	0.02	174.9 A	174.7 A	174.9 A	0.00
Biacromion Length	403.5 A	404.5 A	404.7 A	0.02	355.0 A	357.0 A	355.2 A	0.05
Interscye, Back	406.5 A	405.8 A	406.0 A	0.01	327.8 A	328.2 A	327.6 A	0.01
Scye Depth	179.0 A	179.0 A	178.7 A	0.01	178.4 A	178.2 A	178.5 A	0.00
Waist Back Length	387.9 A	387.3 A	387.5 A	0.01	386.6 A	386.5 A	386.8 A	0.00
NP to Scapula	223.3 A	223.4 A	223.8 A	0.01	236.4 A	237.8 A	237.4 A	0.06
Scapula to Waistline	199.3 A	199.3 A	199.4 A	0.00	197.6 A	198.3 A	197.3 A	0.05
Sideline	188.7 A	188.7 A	189.0 A	0.00	202.6 A	202.3 A	202.9 A	0.01

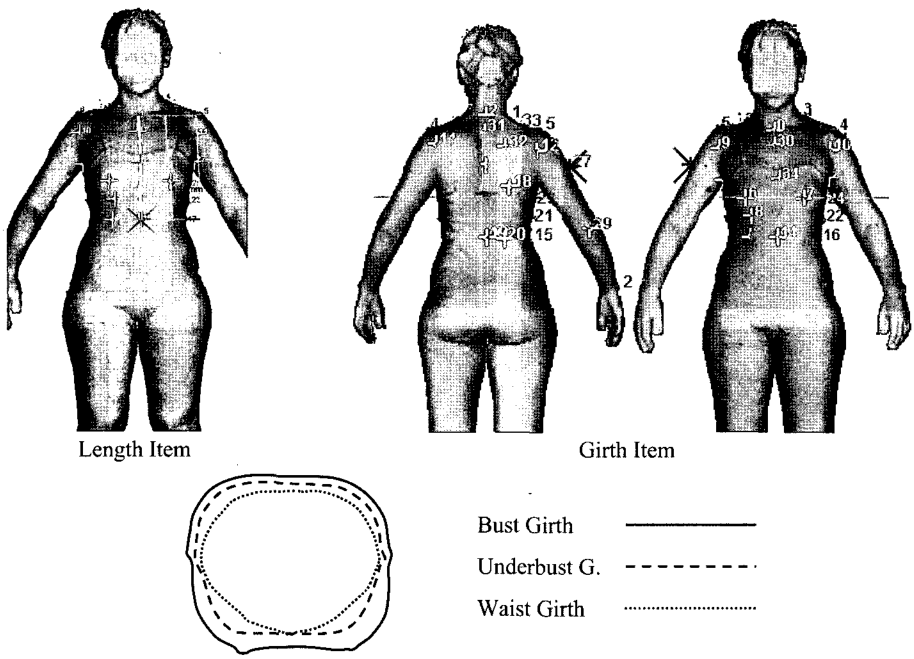


Fig. 8. Illustrations of the measuring process and stacked cross sections generated from scanworx body measure for the anthropometric posture

was developed to automatically derive all important anthropometric measurements from the scan. Many traditional measurements such as lengths, angles, girths, and surface measurements of body lengths can be made manually on the scan using the virtual tools provided by the software. <Fig. 8> is an image showing an example of measuring length and girth using ScanWorX Body Measure. After identifying and tagging the landmarks, the appropriate tool is chosen for measuring. Length tools are included for either straight lengths(point to point) or curved lengths(over the surface of the body). Girth measurements are obtained from the cross sections generated at the appropriate landmark. The small bumps on the cross sections in Figure 8 are the physical raised landmarks that were placed on each subject prior to scanning. The largest girth is the bust, the next one is the underbust, and the smallest is the waist.. Stacked cross sections generated from 3-D scans showed variations in shape from the different postures.

ScanWorX Tailor is the fully automated body measurement system for made-to-measure clothing developed for use with the Vitus scanner. This can be a very useful tool to generate a large number of standardized body measurements for a variety of studies including anthropometric surveys of various populaitons.

Eleven items including height were available to compare on both extraction tools. According to Table 10, t-test result showed significant differences on 5 items. 6 items had differences over 1~2cm. Especially shoulder length, sideline and biacromion length were distinctly disagreeing items. Even though definition of measurement at ScanWorX Tailor looked similar to that of traditional anthropometry, shoulder point was incongruently lowered on the ScanWorX Tailor, and the shoulder length became longer. Automated extraction program was found to have some limitations and be relatively inaccurate than the directly applied manual body measuring tool. Besides, ScanWorX Tailor was not compatible to measure the items for dynamic postures because it could not recognize suitable landmarks at all.

IV. Conclusion

The efficiency of 3-D body scanning, from which

Table 10. Measurements of ScanWorX body measure and tailor (Unit : mm)

Items	Body Measure	Tailor	Difference	t-value
Height	1649	1660	-11	-0.07
Neckbase Girth	384	400	-16	-2.95**
Bust Girth	901	904	-3	-0.27
Waist Girth	744	747	-3	-0.21
Shoulder Length	122	139	-17	-5.77***
NP to BP	280	286	-6	-1.46
BP to BP	181	189	-8	-1.68
Biacromion Length	387	403	-16	-3.11**
Interscye, Back	347	364	-17	-2.85*
Waist back Length	379	374	5	1.01
Sideline	180	198	-18	-3.30**

*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$

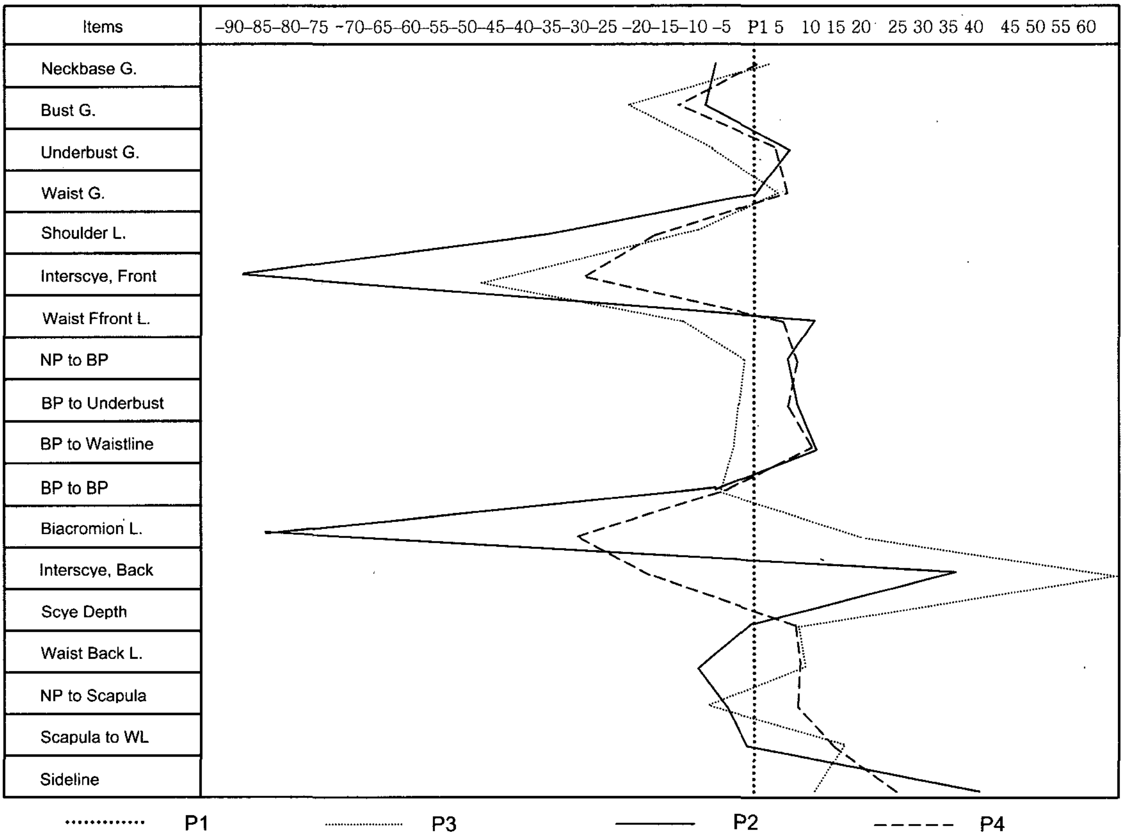


Fig. 7. Body surface change values from scanned data for dynamic postures (Unit : mm)

an infinite number of measurements, body shapes, angles, and relational data can be extracted, is well known. Through the procedures fulfilled, this study investigated the accuracy and the reliability of 3-D body scan measures for body movements as well as standard posture. Especially body surface length and girth changes aroused by dynamic postures were measured and these were compared with the traditional anthropometric data.

Comparing two measuring methods, differences between 3 dimensional scanned measurements through virtual tool and traditional manual measurements for the standard and shoulder flexion posture were -2~20 mm. Girth items showed a little disagreeing value between two methods. But there was no significant difference except neckbase girth, regardless of the measuring methods or postures. Measurements of the upper body items showed significant linear surface change in the dynamic posture. Especially shoulder length, interscye front and back, and biacromion length were the items prominently influenced by dynamic postures. The repeatability of scanned data showed satisfactory results. 3 times repeated scan measurements for the scapula protraction and scapula elevation posture were proved statistically the same for all items. For the results of comparing automatic measuring software with manual one, many measurements from the automatic program were larger and showed some significant differences.

It is possible to collect many dimensions of data in a much shorter amount of time with reliability using 3-D body scanner. Placing physical landmarks on the subject being scanned and using the software tools to manually measure the scan can result in valid and reliable measurements of any kind from a variety of dynamic postures. However, some problems remain that could be solved by supplementary software.

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요 약

3차원 스캐너를 통한 인체 측정치는 다양한 분야에서 사용되고 있다. 본 연구는 이러한 3차원 측정치의 정확성과 신뢰도를 조사하기 위한 것이다. 이를 위해 TECMATH사의 VITUS 전신 스캐너로 인체를 측정, ScanWorX Body Measure 소프트웨어를 이용하여 항목을 측정한 값과 직접 인체측정에 의해 얻어진 값을 비교하였다. 피험자는 평균 체형의 미국 여대생 25명이며 기준 자세와 일상생활에 많이 쓰이는 135° 양팔 들기, 어깨 구부리기, 어깨 들어올리기의 3가지 동적 자세를 실험 동작으로 하여 체표의 길이 및 둘레의 변화를 측정하였다. 기준 자세와 135° 양팔 들기에 대한 측정치 비교에서 두 가지 측정법에 의한 항목들의 차이는 -2~20mm였으나 두 동작 모두에서 목둘레만이 유의한 차이가 있는 것으로 나타났다. 또한 길이항목보다 둘레항목에서 좀 더 큰 차이를 보였다. 실험 동작에 의해 상반신 18개의 측정항목들은 유의한 체표변화를 나타내었으며 특히 어깨길이, 겨드랑앞벽사이길이, 겨드랑뒤벽사이길이 그리고 견봉사이길이에서 뚜렷한 변화가 나타났다. 그러나 두 측정법에 따른 체표변화 차이는 없었다. 어깨 구부리기와 어깨 들어올리기 동작시에는 스캔 측정을 3회 반복함으로써 3차원 측정치의 신뢰도를 조사하였는데 모든 항목에서 3회 반복된 측정치가 통계적으로 동일한 것으로 나타났다. 또한 ScanWorX 소프트웨어의 가상적 도구인 Body Measure와 자동 프로그램인 ScanWorX Tailor의 측정치를 비교한 결과 자동 측정치가 더 큰 값을 보였고 사용한 프로그램에 따른 유의한 차이를 나타내는 항목들이 나타났다. 이상의 결과로 3차원 인체 측정기를 사용함으로써 짧은 시간에 동작을 촬영하고 이에 대한 측정치를 얻을 수 있어 편리함과 신뢰도에 있어서 장점을 가짐을 확인할 수 있었다. 그러나 좀 더 다양한 분석과 정확한 결과를 얻기 위해서는 의복 분야에 유용한 자동 프로그램의 개발과 3차원 인체 측정기 간의 호환성의 문제들이 요구된다고 할 수 있다.