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COMPARITIVE ANALYSIS OF THE IMAGE TWIN SYSTEM AND THE 3T6 BODY SCANNER

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ABSTRACT

Technology has radically changed the manner in which anthropometric data is collected. Consequently, the apparel industry along with others has begun to explore utilizing this technology to provide mass customization, improve ergonomical design, and an array of other applications. There is a need to better understand how these measurements coincide with comparable physical measurements. This study evaluated the body scan data rendered by two TC^2 scanners, the Image Twin (2T4) and the 3T6 in comparison to physical measurements. Results suggest that there has been significant improvement in the newer version, Image Twin, however there are still many areas that need to be explored further as is detailed in this article.

KEYWORDS: 3D Body Scanning, mass customization, body measurements, anthropometry, measurement extraction software, Image Twin, body scanners, physical measurement

Introduction

The last decade of the 20th century brought about a revolution in anthropometry. The development of existing technology made it possible to collect anthropometric data using a non-contact body scanner (Paquette, 1996). This technology eliminated the greatest hindrances to anthropometric surveys: time and data reproducibility. Once created, the image file can be used again and again to extract the same descriptive information, reliably. Error can be introduced to the data however, through the lack of standardization that currently exists in the scanning process. Respiration is just one of the known factors that can affect critical measurements in the torso (Daanen, Brunsman, & Robinette, 1997, Mckinnon, 2000).

Body Scanning technology has the potential to impact applications from apparel to healthcare. The apparel industry is perhaps the most advanced user, currently. The use of body scanning technology for customization, apparel design, and development has come to the forefront and is an integral part of the industry's vision of the future. Since the concept is still in its developmental stages, few retailers and manufacturers have adopted this technology. Levi, once the sole company in the US exploiting this technology, has recently been joined by Land's End. This may be attributed to the fact that many companies fail to see profitability in this endeavor and remain locked in a traditional mentality. Most manufacturers and retailers still believe in the ancient concepts of mass production and sizing charts in spite of innumerable consumer complaints and dissatisfaction with ready-to-wear. While these concepts still hold some validity, it is diminishing (Jones, & Rioux, 1997; Paquette, 1996). Body Scanning also has applications in the military, which was one of the first industries to realize the potential of the technology. It is crucial that up-to-date and accurate body measurements are available for designing aircraft cockpits, pilot helmets, oxygen masks, tank interiors, and uniform design. The military recognizes the performance and cost advantages they stand to gain. Other applications of this technology also exist in such things as prosthesis design, craniofacial surgeries, and museum exhibits (Jones, & Rioux, 1997; Paquette, 1996).

Objective

The objective of this study was to examine two versions of the TC^2 scanner and compare them with traditional anthropometric measurements. The two versions evaluated were the 3T6 and the Image Twin 2T4. Both systems operate using the white light PMP (Phase Measuring Profilometry) approach. The 3T6 has three towers, each with two CCD cameras and two projectors. The 2T4, with the smaller footprint, has only two towers, each with two CCD cameras and two projectors. A vertical triangulation is formed between the camera, projector, and the human body to capture the three-dimensional data points necessary to create a three-dimensional image of the human body. Other differences in the systems include an updated version of the TC^2 Body Measurement System extraction software on the 2T4 system and increased data points in the upper region of the scanned subject to achieve improved measurement extraction accuracy.

Materials and Methods

<u>Sample</u>

Wolf dress forms were used as the scan objects in this study. Dress forms were utilized to minimize possible sources of measurement error such as movement artifacts due to respiration, body sway, and subject posture. The five male and five female dress forms used, represented diverse body types and were obtained from the U.S. Army Natick Base and are the same forms used in the Natick study of automated measurement extraction packages (Paquette, 2000). These forms, shown in Figure 1, were custom-made by Wolf Form Inc. for the U.S. Army.

Figure 1. Wolf dress form

Measurement Protocol

Three trained anthropometrists measured and recorded each dimension three times using a tape measure to the nearest sixteenth of an inch. To minimize error, one anthropometrist measured while the other recorded the data. The average of all nine measures for each dimension was deemed as the physical measurement for that dimension. Table 1 lists each dimension examined in this study along with its comparable measure according to the U.S. Army and ISO-8559. All dress forms were scanned three successive times in each scanning system (2T4 and 3T6). Between each scan, the dress forms were removed and repositioned in the scanner in order to evaluate the effect of positioning on measurement consistency. Scanned measurements of each form were extracted using the software of the respective system in which the scan was taken.

Statistical Analysis

There are several statistics for quantifying instrument error. There was no consistency in the statistical methods used in other studies of similar nature (Gordon, C. and Bradtmiller, B., 1992; Marks, C., Habicht, J., and Mueller, W., 1989; Williamson, D., Kahn, H., Worthman, C., Burnette, J., and Russell, C., 1993). In this study we used the mean absolute differences (MAD) to quantify the measurement error in each of the dimensions for both the 3T6 and the 2T4 systems. The mean absolute difference was calculated by averaging all the absolute differences between the scanned measurement and the average physical measurement for all subjects. The absolute differences were utilized to incorporate both negative and positive difference, without negating each other. Any measurements shown to be outliers were eliminated from the data pool to prevent skewing of the results. The MAD was also calculated for both sexes to determine if gender had any effect on the precision of the data. Allowable limits of error were set for each of the measurements (see Table 2). These limits were set in accordance with the U.S. Army's Measurer's Handbook. A one-way analysis of variance was used to identify differences among the two measuring systems.

Results and Discussion

Of the ten measurements examined on each of the ten dress forms, two measurements (waist circumference and hip circumference) were within the allowable limits of error for the 3T6 scanning system. Four measurements (neck circumference, waist circumference, hip circumference, and thigh circumference) were within the allowable limits for the 2T4, which exhibited a higher level of precision (See Table 2). The MAD values of the dimensions were smaller for the 2T4 than the 3T6, but more importantly the precision of each measure was higher for the 2T4 than the 3T6 as shown in Figure 2 and 3. These Figures show the highest and lowest MAD for each dimension and the average MAD denoted by the boxes. Figure 2 demonstrates that the high and low values were closer to the mean in the 2T4 system.

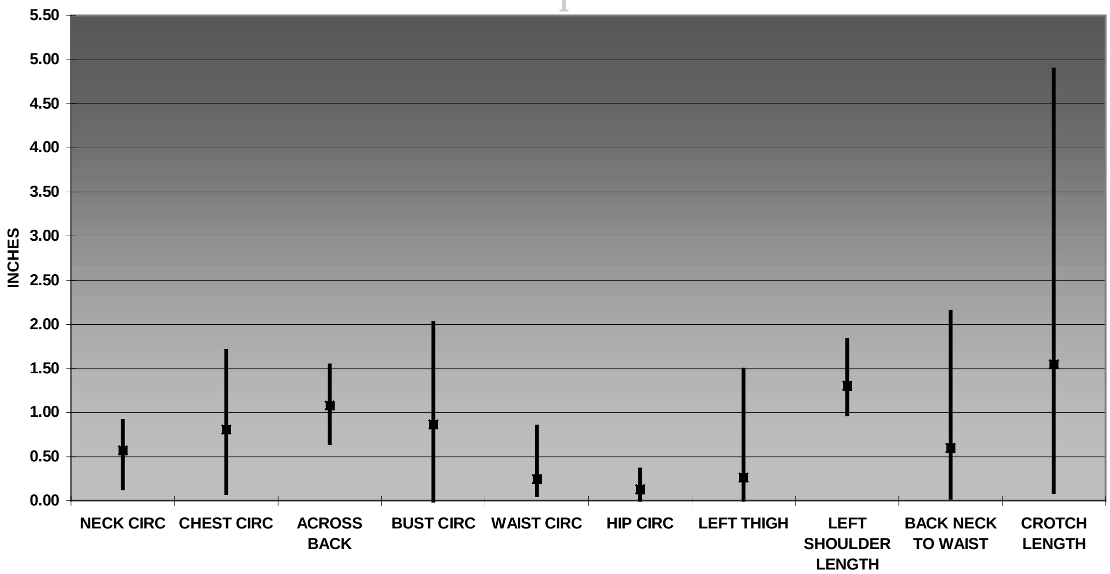
Table 1. Anthropometric Measurements Recorded on Each Dress Form

Body Dimension	***US. Army Var No.***	***ISO-8559 Var. No.***
Neck Circumference	80	2.1.3
Chest Circumference	33	2.1.7
Across Back	69	2.1.6
Bust Circumference	34	2.1.8
Waist Circumference	113,114	2.1.11
Hip Circumference	23	2.1.12
Thigh Circumference	103	2.1.18
Shoulder Length	91	2.1.4
Waist Back Length	110,111	2.1.10
Crotch Length	39,40	2.2.19

Table 2. Descriptive Statistics of the two Scanning Systems

Dimension	n	Allowable error in inches	3T6 MAD	% of population within allowable error	2T4 MAD	% of population within allowable error
Neck Circumference	30	0.197	0.57	10	0.17	70
Chest Circumference	30	0.591	0.81	43.3	0.78	26.7
Across Back	30	0.197	1.08	0	0.72	0
Bust Circumference	30	0.394	0.86	40	0.52	50
Waist Circumference	30	0.433	0.25	80	0.11	100
Hip Circumference	30	0.472	0.15	90	0.14	90
Thigh Circumference	30	0.236	0.26	43.3	0.14	96.7
Shoulder Length	30	0.118	1.30	0	1.05	0
Back Waist Length	30	0.197	0.59	26.7	0.44	33.3
Crotch Length	30	0.630	1.55	40	1.06	30

Figure 2. High-Low-Average MAD of the 3T6.



The neck circumference measurements yielded by the 3T6 exceeded the physical measurements by an average of 0.57 inches whereas the 2T4 was had a mean absolute difference of only 0.17 inches, well within the allowable error limits. Both systems handled waist circumference, hip circumference, and thigh circumference with relative ease. The measurements extracted by these systems deviated only by small increments and all were within the allowable limits except thigh circumference as found by the 3T6 system. It should also be noted that the percentage of the sample that was found to be within the allowable limits for all of these dimensions was greater for the 2T4 system then the 3T6 for these measurements. The greatest improvement

Figure 3. High-Low-Average MAD of the 2T4 Scanning System.

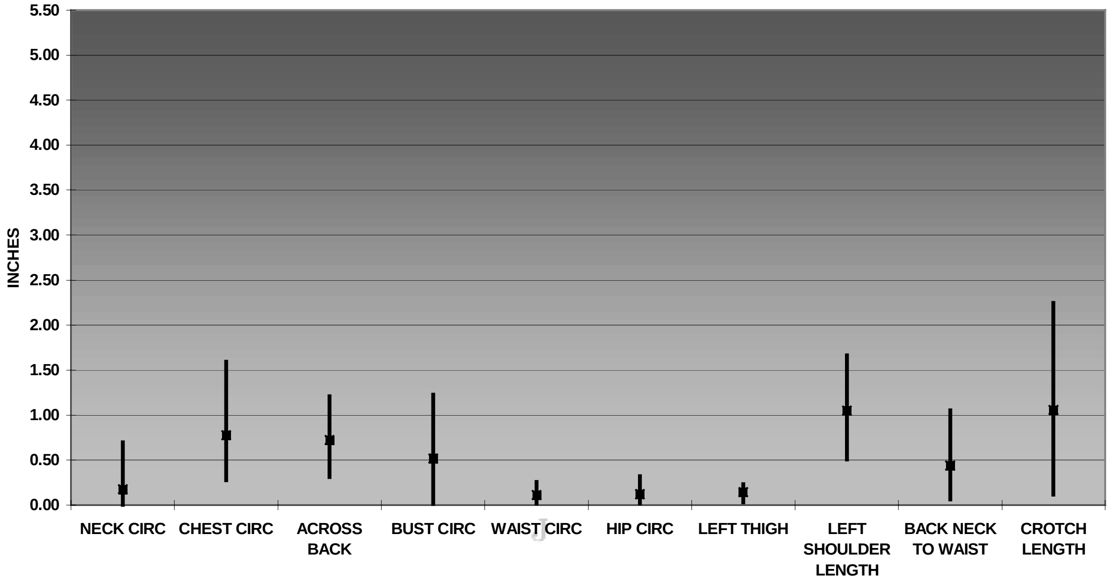
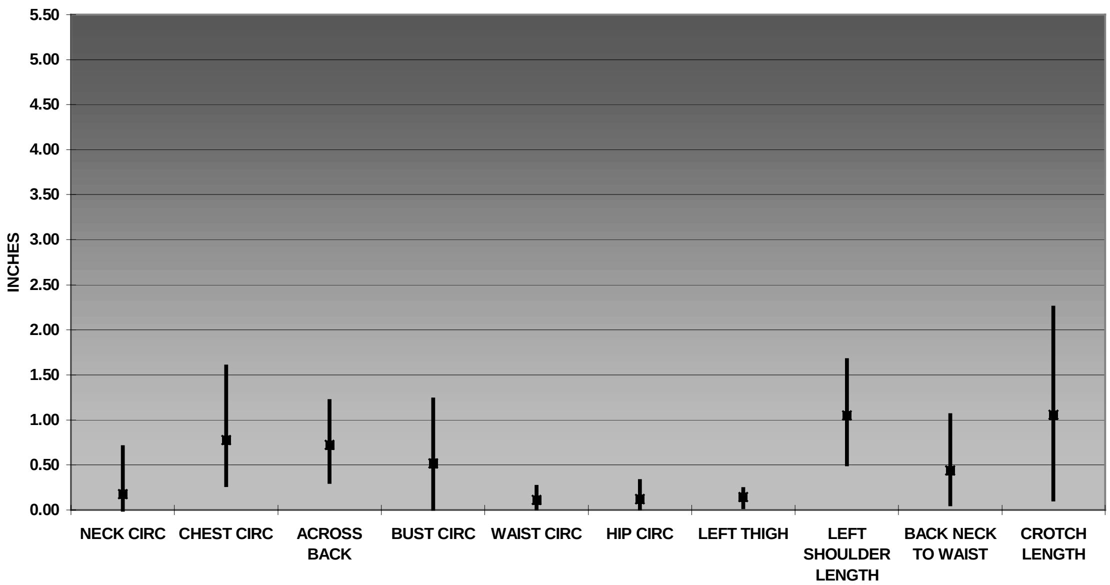


Figure 3. High-Low-Average MAD of the 2T4 Scanning System.



was thigh circumference in which the percentage of the sample that had a MAD within the allowable error limits increased from 43.3% to 93.7% in the 2T4 system.

Neither system was able to extract bust circumference or back waist length with extreme accuracy, although the 2T4 system (MAD =0.52 inches) did yield better results than the 3T6 (MAD = 0.86 inches). It was noted, however, that extraction of the bust measurement was more precise in the female dress forms than it was in the male forms. The MAD for the female forms scanned in the 3T6 was only 0.26 inches and 1.27 inches for the male forms. Female dress forms scanned in the 2T4 had a MAD of 0.23 inches and male forms had a MAD of 0.73 inches. This is most likely due to the fact that both the 3T6 and the 2T4 are non-contact scanners that utilize algorithms to locate critical landmarks and calculate measurements. Since there is an absence of physical landmarks, it is more difficult to locate certain landmarks in a male form for each dimension. Females, by nature, have larger busts that protrude from the body markedly distinguishing the bustline.

The measurements that both systems had the most difficulty with were across back, shoulder length, chest circumference, and crotch length. Physical measurements of the across back dimension exceeded the scanned measurements in both the 3T6 and the 2T4 systems. Neither system came even close to the measurement error limits. The scanned measurements were an average of 1.08 inches less for the 3T6 and 0.72 inches for the 2T4. The inability of the scanning systems to capture data points in shaded areas of the body such as the armpits is the most likely reason for the shortcomings of scanned data. The physical measurements of crotch circumference also consistently exceeded the scanned measurements of both the 3T6 and the 2T4. In contrast, the measurements of the two scanning systems exceeded the physical measurements of shoulder length and chest circumference in every measurement. Shoulder length is one measure that the scanning systems would over measure by about an inch on every scan. This again is most likely due to the inability of the system to accurately locate the acromium (a critical landmark for this measurement).

Conclusions

Scanning systems utilized for obtaining anthropometric dimensions have made advances since their introduction approximately a decade ago. Based on comparative measurement data, it is clearly evident that the 2T4 is an improvement over the 3T6. Though the measurements of the 2T4 were not always within the allowable error, the system as a whole always produced data that more closely replicated the physical measurement process. However, areas of needed improvement still remain. Since the system is a non-contact scanner based upon white light technology, it is more difficult for the system to identify body landmarks and also obtain enough data in crucial areas, which are often hidden by pose or shadow. The greatest improvements were made in neck circumference, bust circumference, waist circumference, and thigh circumference. These measurements had a significant decrease in the mean absolute difference and/or a significant increase in the percentage of measurement error that fell within the allowable limits.

In conclusion, it has been demonstrated that the 2T4 system examined here performed more closely in accordance with traditional anthropometry than the 3T6 system. However, additional refinements are needed for some dimensions. The results are promising that automated anthropometric data extraction systems are headed in the right direction to yield fast and accurate data.

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