A three-dimensional quantitative biomechanical analysis of left handed scanning

by

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A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Biomedical Engineering

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Iowa State University

Ames, Iowa

2007

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CHAPTER ONE: INTRODUCTION

Cumulative trauma disorders (CTDs) are a class of pathologies affecting muscles, nerves and tendons due to repeated exertions and excessive movements. The incidence of CTDs has grown significantly over the past few decades in the supermarket industry. The U.S. Bureau of Labor Statistics reported that the percentage of occupational illness attributed to CTDs in 1981 was 18%, in 1991 was 62% and in 2000 was 69 % (38). CTDs that are specific to the hands and wrist involving the muscle tendon unit include tendonitis, De Quervain tenosynovitis and trigger finger. Tendonitis is an inflammation of the tendon and occurs mostly at the elbow. De Quervain tenosynovitis is a narrowing of the passageway of the tendons and their sheaths that extend to the thumb, resulting in pain in thumb motion. Trigger finger is caused by a narrowing of the canal in which the finger flexion tendon and sheath travel. All of these diseases have been documented in the workplace. However CTDs involving the nerve, such as carpal tunnel syndrome (CTS), are most associated with supermarket, grocery, and retail cashiers because of the repeated flexion–extension of the wrist. CTS is caused by the compression of the median nerve at the wrist as it travels through the carpal canal. The pure nature of the work of cashiers in the supermarket industry and their repetitive wrist motions lead many researchers to note that CTS is the most common disease of CTDs in this environment (19,22,23,27). CTS was diagnosed in 180,000 U.S. employees from 1999–2002 (26,39). Armstrong and Chaffin (3) estimated that CTS was clinically and electrophysiologically confirmed in the general population at 2.7%.

CTS is a common disorder of the upper extremities and occurs at the median nerve, which travels from the forearm into the hand and becomes pressed at the wrist.

The median nerve controls sensation to the palm side of the thumb and fingers as well as impulses to some small muscles in the hand that allow the fingers and thumbs to move (15). The carpal tunnel is a narrow rigid passageway of ligament and bones at the base of the hand, which contains the median nerves and tendons. Occasional thickening from irritated tendons or swelling narrows the tunnel and causes the median nerve to be compressed. This may result in pain, weakness or numbness in the hand and wrist, radiating up the arm. Although painful sensations may indicate other conditions, CTS is the most common and widely known of the entrapment neuropathies in the body's peripheral nerves that are compressed and traumatized (15).

Symptoms

Symptoms of CTS usually start gradually with frequent burning, tingling, itching or numbness in the palm of the hand and fingers, especially the thumb, index and middle finger. Patients report that their fingers feel useless and swollen, although minimal swelling may be apparent (4). Symptoms often first appear in one or both hands during the night, because many individuals sleep with a flexed wrist. As symptoms increase patients may feel tingling during the day (4,9). Decreased grip strength may make it difficult to form a fist, grasp small objects or perform manual tasks. In chronic or untreated cases, the muscles at the base of the thumb may pulsate. Clinical diagnosis of CTS is done by an electrical conduction test of the median nerve for evidence of entrapment in the carpal tunnel. This test is the gold standard for diagnosing CTS.

Origination of CTS

CTS is often the result of a combination of factors that increase pressure on the median nerve and tendons in the carpal tunnel rather than a problem with the nerve itself.

Other contributing factors include trauma or injury to the wrist that causes swelling, such as sprains or fractures; excess activity of the pituitary gland; hypothyroidism; rheumatoid arthritis; mechanical problems in the wrist joint; work stress; repeated use of vibrating hand tools; fluid retention during pregnancy or menopause; or the development of a cyst tumor in the carpal canal (22).

Employees at High Risk

Employees who have a higher risk of developing carpal tunnel syndrome are not just those in a single industry or job; however the odds of developing CTS are common for those who perform assembly-line work, manufacturing, sewing, cleaning and grocery retail. CTS is three times more common among assemblers than among data entry personnel (4). During 1988 an estimated 3 of every 10,000 workers lost time from work because of CTS (26). More than half of these workers missed over 10 days of work (26). The average lifetime cost of carpal tunnel syndrome patients ranges from $30,000–$50,000. This includes medical bills, lost time and diminished work production (26).

Davis et al. (7) reported in a population-based study in Massachusetts that patients with self-reported carpal tunnel syndrome tended to have jobs with bending or twisting of the wrist or the use of hand tools as part of their work. A study by Ferry et al. (11) found that 1,210 employees from 53 different companies in France doing repetitive work showed increasing risk factors with a decrease in cycle time of repetitive motion (11). Occupation categories with high diagnoses of CTS include mail delivery, health care, retail and assembly line workers.

A study by the National Institute for Occupational Safety and Health concluded that there was evidence of CTS with highly repetitive work, forceful work and hand-wrist

vibration (26). The evidence appeared very strong for a combination of risk factors, such as repetition and force posture. According to the U.S. Bureau of Labor Statistics (2004), grocery stores rank fifth in the number of CTS cases reported. Cashiers during a 4-hour shift may flick their wrist back and forth up to 600 times per hour (38). The repetitive nature of front-end scanning has been recognized in studies by Margolis and Kraus (19).

Harber et al. (13) reported evidence of a clear relationship between front-end checkers and CTS. In their study 12 of 32 supermarket checkers reported pain in their hands, wrist and fingers. Nine of 30 checkers reported tingling in this same area and four reported weakness in their hands. Research in this industry proves that there is a high incidence of CTS in grocery workers who scan multiple grocery items. However, to date there has been very minimal research analyzing left-handed scanning of multiple items over time and assessing the risk of CTS.

Thesis Overview

The purpose of this study is to gather, compare and contrast kinematics data of left handed scanning of 17 multiple grocery items to the industry's standard developed by Marras and Schoenmarklin (22). Another goal of this study is to define any relationship between left-handed scanning and the causation of CTDs that may lead to CTS. Data were analyzed using paired difference t tests and two sample t tests implemented in SAS computer software. Each subject participated in a 4-hour before and after trial experiment that consisted of the beginning time of scanning compared to the ending time of scanning after a 4-hour period. Parameters that were monitored included angular velocity, angular acceleration, and position of the left hand and were analyzed by MATLAB computer software. Measurements were made in three planes: pronation/supination, flexion/

extension and radial/ulnar. Kinematic data were recorded by a 3–Dimensional Peak Motus Camera System.

This research was conducted with 11 subjects, 7 males and 4 females, with at least 2 years of prior grocery scanning experience. Two subjects, one male and one female, were used for a pilot study to test the equipment and data. The project description was submitted to the Institutional Review Board for approval. Approval was granted in November of 2005, and data were collected early in 2006.

This chapter discussed the prevalence of CTDs and CTS in the workforce and its relevance to wrist mechanics Research in this area is justified because of the number of employees diagnosed with musculoskeletal disorders. Chapter Two expands on the literature research of CTS, particularly among workers in occupations with high repetitive hand and wrist motions in the supermarket, frozen food and construction industry. This chapter also mentions non-biomechanical factors that may affect CTS such as gender, age, body mass and weight. Chapter Three outlines the experimental protocol implemented during the scanning and describes the video tracking equipment used to collect and analyze data. Chapter Four provides the data and presents the results that were obtained from nine individuals in the test experiment. Chapter Five interprets the results of this experiments and recommends further research needs.

CHAPTER TWO: LITERATURE REVIEW

Occupational

The impact of ergonomic injures are cited in numerous studies (20,21,22,37,38, 40,42). Roughly one third of all occupational injuries and illness are the result of over exertion and repetitive motion. The cost to the industry in worker's compensation ranges from $12 to $20 billion annually. Carpal tunnel syndrome produces more days away from work on average than any other workplace injury (38). The median number of days away from work is 25 days compared to 17 days for fractures and 20 days for amputation (38). Employees with extreme or severe injures can face permanent disability, which can prevent them from performing everyday tasks (e.g., using a can holder, pouring milk, or flicking the television remote control).

Grocery and Supermarket

Supermarkets have one of the highest incidences of CTDs associated with repeated trauma. Most grocery store workers are exposed to a variety of high repetitions of forceful hand and wrist motions. Margolis and Kraus (19) recognized the potential of checking work for producing CTS through questionnaires and anecdotal clinical records. Front-end checkers, butchers, florists and cake decorators appear to have the most risk for developing CTS. Osorio et al. (27) found that the overall prevalence of CTS among grocery workers was 23% and that CTS is a major cause of lost workdays and worker's compensation costs in the United States. Osorio et al. also reported that an estimated 47% of CTS disorders are work related.

Technological advances in this industry may have increased rather than decreased the risk of injuries. Specifically, cashier stations with laser scanners allow the checker to

scan more items thus increasing their work production but causing more wrist repetitive movements in a given time period (13).

Anthropometrics

The bones on the bottom and ligaments on the top of the wrist create the carpal tunnel (Figures 1 and 2). The median nerve runs through the tunnel along with the flexor tendons to the wrist. Pressure within the tunnel can compromise the nerve and cause carpal tunnel syndrome. The hallmark of carpal tunnel syndrome is numbness in the thumb, index and middle finger. Additional symptoms can include weakness in the thumb muscles of the hand and soreness in the index finger during nighttime sleeping. Tanaka et al. (36) reported that the friction between adjacent structures and tendons is a major cause of hand and wrist CTS. Marras et al. (21) reported that the frictional work generated in the carpal tunnel is dependent between repetition and CTDs/CTS risk.

Occupational factors such as repetitive wrist motion, posture and the relationship with CTDs/CTS have been reviewed and discussed in many articles (1,2,30,31,32). The overall findings from the literature support the fact that greater forces in the flexor muscles will generate increased frictional work between the flexor tendons and their adjacent structures, thus increasing CTDs/CTS. Armstrong and Chaffin (2) focused on the histological changes in the flexor tendons that pass through the carpal cannel and discovered that hyperplasia increased density in the synovial tissue in the carpal tunnel area. Repeated motions and exertions with a flexed or extended wrist can cause partial or permanent damage to the tendon tissue. Marras et al. (21) reported that the flexion/ extension angle increases shear traction forces between bones, ligaments, tendons and

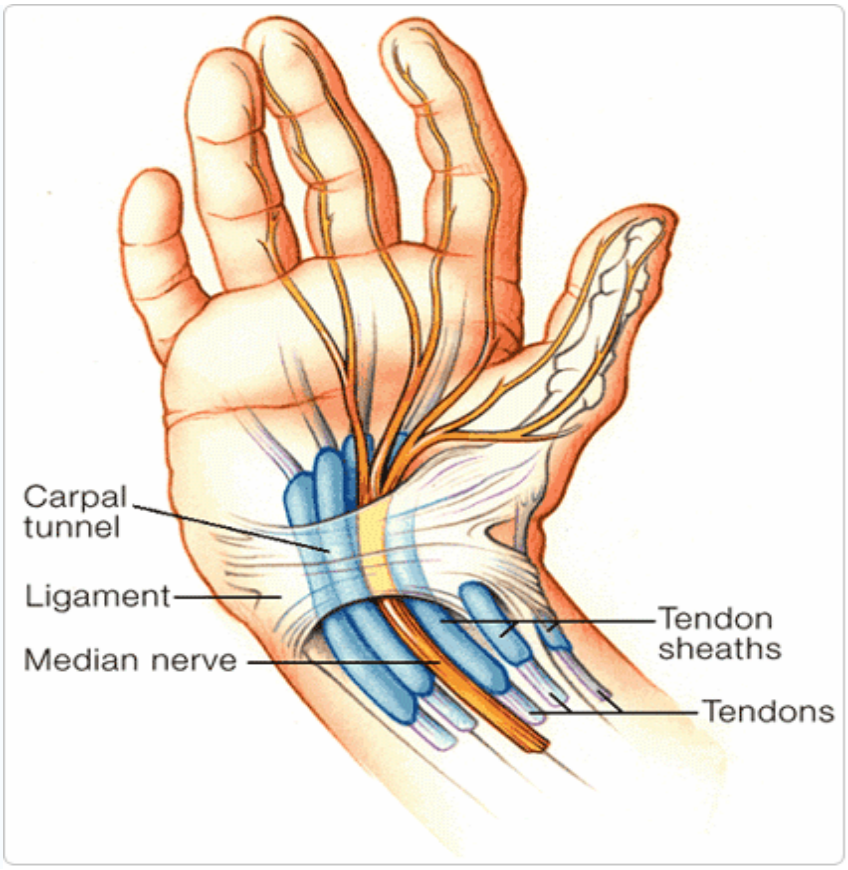

Figure 1: Tissues and ligaments comprising the carpal canal.

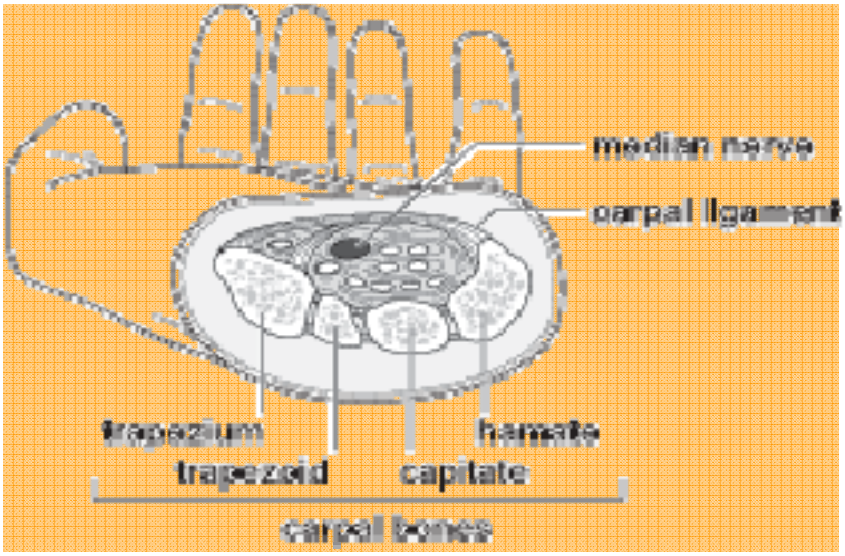

Figure 2: The carpal tunnel. Consisting of eight bones of the wrist, of which four are shown here: scaphiod, lunate. triquatal, and pisoform; and four distal carpals (capitaite, trapezium, trapezoid,and hamate). The tendons that connect the forearm flexor muscles to the fingers pass through the carpal tunnel.

their sheaths. The stresses at the tendon–sheath interface are significant and depend on the flexion/extension wrist angle.

Armstrong (1) found that the wrist tendons in the flexion/extension plane showed that angular deviations from the neutral position generated large resultant reaction forces on the flexor tendons. When the tendons are accelerated, the resulting reaction force exerted on the tendons by bones increase dramatically as compared to static loading. The resulting forces on the tendons from the flexion/extension acceleration could degenerate and inflame the flexor tendons passing through the carpal tunnel, thus compressing the median nerve, which can cause CTS.

Another common cause of CTS is inflammation of the tendons in the carpal tunnel, which can be attributed to repetitive use of the hand and wrist motion in positions that may create increased fluid pressure in the carpal tunnel. Several studies have shown that an increase in fluid pressure in the carpal tunnel of 40-50 mm Hg sustained for 60 minutes can result in transient nerve changes in nerve function, whereas as little as 30 mmHg of fluid pressure over 4 hours can cause prolonged effect on tissue (1,2,5,9,16). Repetitive twisting of the forearm while scanning in the pronation/supination position as well as wrist flexion and extension increases the fluid pressure in the canal. Armstrong and Chaffin (2) noted that tissues within the carpal tunnel are subjected to increasing fluid pressure as the forearm is rotated from the neutral position of 45-degree pronation to full supination. This rotation of the forearm commonly associated with scanning grocery items can potentially increase the fluid pressure in the carpal tunnel by as much as 285% (18).

Wrist Mechanics

Wrist motions include accelerations, velocities, pronation–supination, radial–ulnar and flexion–extensions. Angular velocity and acceleration contribute to the risk of CTS and CTDs (10).

Velocity

Velocity is the speed of a moving body and can change both in magnitude and direction. As such the velocity, $\mathbf{v}(t)$, is a vector quantity that varies with time. If the position of the body in two-dimensional space is a known function of time and is denoted by both **x(t)** and **y(t)**, then:

$$v_x(t) = \frac{dx(t)}{dt} \quad v_y(t) = \frac{dy(t)}{dt},$$

which is measured in units of distance over units of time.

Angular Velocity

Angular velocity, ω, of a rigid body is the rate of change of its angular position (units are radians per second) and is computed as:

$$\omega = \frac{|\mathbf{v}| \sin(\theta)}{|\mathbf{r}|} \hat{n}.$$

Acceleration

Acceleration is the "rate of change of velocity of an object with respect to time" and the instantaneous acceleration of an object is given by the equation:

$$\mathbf{a} = \frac{d\mathbf{v}}{dt}.$$

Angular Acceleration

Angular acceleration is the rate of change of angular velocity with time given by the equation:

$$\alpha = \frac{a_t}{r},$$

where a_t is defined as tangential acceleration. In addition to an angular acceleration there is always a centrifugal acceleration given by the equation:

$$a_c = \frac{v^2}{r}$$

Wrist angular acceleration increases reaction forces on the flexion tendons and median nerves. This reaction contributes to the development of CTS. Armstrong and Chaffin (2) noted that the association between tendon forces and CTDs is a result of reaction forces of tensile and shear forces on the tendons. This resultant force contributes to inflammation and deterioration of the tendons. Wrist postures, repetition, tendon force and wrist acceleration are the four major contributors to CTDs. Wrist posture along with angular acceleration and velocity have been cited as a risk factor for CTS and CTDs (1).

Based on Newton's second law of motion, the extrinsic muscles in the forearm must exert a force proportional to the angular acceleration of the hand (22). Newton's second law of motion can be formally stated as follows: The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.

From Newton's Second Law: **Force = mass * acceleration**

In three dimensions: F tangential (Ftan) = mass* acceleration tangential (atan)

However, the angular acceleration, α, and the tangential acceleration atan are related by: atan = r α then Ftan = m r α

Multiplying both sides by r (the moment arm), the equation becomes:

Ftan r = m r ^{2} α

Note that the radial component of the force goes through the axis of rotation, and has no contribution to torque. The left hand side of the equation is torque. For a whole object, there may be many torques. So the sum of the torques is equal to the moment of inertia (of a particle mass, which is the assumption in this derivation), **I** = m **r** ^{2} multiplied by the angular acceleration, α. Thus giving the equation:

$$\sum \tau = I \cdot \alpha$$

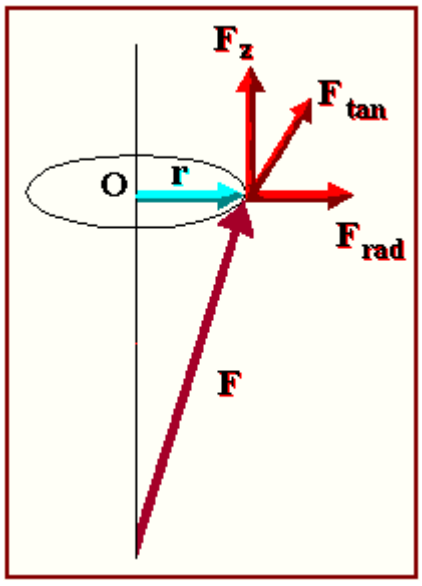

Figure 3: Radial tangential and z –components of forces in three dimensions

Acceleration is important in this experiment because most grocery checkers assume pinch grips during scanning. This position increases tendon tension by secondary wrist movers that are connected to the fingers. Since these tendons pass through the carpal canal, increasing acceleration would increase the chance for CTS (5).

Wrist Dimension and Size

Dyck et al. (9) noted that wrists that has a square shape, a small size hand or a narrow carpal canal gap, have a larger prevalence of association with CTS. A relationship between a more squared shaped wrist and median neuropathies of the wrist were also documented by Johnson et al. (14). Some studies have suggested a square shape wrist and findings of mononeuropathy at the wrist (14,28). Deviations of the wrist in the flexion/extension plane have been shown repeatedly in the anatomical and physiological literature to increase carpal canal pressure (12). In a flexed or extended posture the median nerve is squeezed between the flexor retinaculum and the underlying flexor tendons, thus leaving the individual exposed to CTS (12).

Aging

Aging has consistently been associated with slowing of the median nerves across the wrist and contributing to CTS (8,17,24,33). Studies have demonstrated a positive correlation of tissue decline as age increases. Stetson et al. (33) demonstrated a decrease in nerve conduction velocity and sensory amplitude contributes to a reduction of fiber diameter and changes in the fiber membrane that are associated with aging. The incidence of CTS in the general population increases with age, with the peak between 45 and 55 years of age (4).

Height

A study of nerve conduction measures by Stetson et al. (33) predicted a strong relationship between height and median and lunar sensory distal latencies ($p < 0.001$) and a negative association with sensory amplitudes in all nerves tested ($p < 0.01$). This finding suggests including height as an important predictor of distal extremity nerve conduction.

Gender

Gender has been suggested as an independent risk factor for the development of CTS as well as repetitive strain injuries (19,23,32). The risk is not well explained, although women had a higher use of the health system. Stevens et al. (34) suggested that women were more likely than men to have a higher prevalence of CTS. In this study it was noted that women have a smaller carpal canal than men, thus exposing them to more nerve compression of the median nerve.

Body Mass Index

Several investigators have reported that individuals with CTS were heavier and shorter than the general population. Cannon et al. (6) noted that 27% of individuals with CTS were obese compared to 12% of the control population. Dyck et al. (9) found an increased prevalence of CTS within an adult population among individuals with shorter stature, greater weight and recent weight gain. The body mass index (BMI) was significantly higher in the CTS group: 27 kg/m^2 versus 25 kg/m^2, $p = 0.001$ (1). Nathan et al. (25) demonstrated that a higher BMI was associated with a higher prevalence of median mononeuropathy. They found a relative risk of 4.1 for obese individuals compared to slender individuals. Werner et al. (41) supported the findings that

individuals with higher BMI are at increased risk for CTS. Letz and Gerr (17) found in a group of 6,000 Vietnam veterans a relationship between obesity and slow conduction of the median nerves across the wrist. However, an inverse relationship was found between obesity and other peripheral nerves. The conduction velocity of the peripheral, sural and ulnar nerves all tended to improve among subjects who were more obese, whereas the median sensory nerves across the wrist demonstrated slowing. This finding suggests that BMI is correlated with the median nerve but not the ulnar sensory distal latencies and that the condition of obesity affects the nerves differently. Increased fatty tissue within the carpal canal or hydrostatic pressure through the carpal canal in obese individuals may explain the relationship between obesity and the slowing of the median nerve across the wrist (1). The median nerve is more compartmentalized than the ulnar nerves and subjected to a build up of fats within the carpal canal in overweight individuals.

CHAPTER THREE: METHODS

Subjects

Two different sets of test subjects were used in this project. A pilot study consisted of one male and one female (Table 1). The actual study consisted of six males and three females. The subjects were chosen because they had two years of prior retail scanning grocery experience and had no form of CTDs/CTS. Iowa State University's Human Subjects Review Committee approved the use of test subjects for this study. The procedure was explained to each subject and each signed a consent document as required by Iowa State University. During an orientation session an opportunity to ask the principal investigator about any aspects of the experiment was provided. Height, weight, age and BMI measurements were recorded for each subject as shown in Tables 1 and 2.

Table 1: Sex, height, weight, BMI and age of pilot study participants

Test Subject	Sex	Height (m)	Weight (kg)	BMI (kg/m^2)	Age
1	M	1.74	88.2	29.1	19
2	F	1.70	54.9	19.0	22

Table 2: Sex, height, weight, BMI and age of study participants

Test Subject	Sex	Height (m)	Weight (kg)	BMI (kg/m^2)	Age
1	F	1.70	59.0	20.4	23
2	M	1.83	68.7	20.5	24
3	F	1.69	55.2	19.5	26
4	M	1.78	66.9	21.1	21
5	M	1.72	74.6	25.2	19
6	M	1.81	66.2	20.2	21
7	M	1.71	68.6	23.2	28
8	F	1.64	52.3	19.4	20
9	M	1.75	110.2	36.0	31
Mean	NA	1.74	72.9	23.8	23

Procedure

Maximum and minimum data points were the data points produced on a MATLAB (Matrix Laboratory) Computer Program that describes the initial time the subject scanned the grocery item (minimum point) to the time the subject finished scanning the grocery item before placing the item on the table (maximum point). Seventeen maximum and minimum points were collected for each subject during the experimental trial. Angular velocity, angular acceleration, position were collected in three planes: radial/ulnar, flexion/extension and pronation/supination. The 17 data points represented the grocery items being scanned. The data were collected at time initial (beginning) and at time end (4 hours) for each subject . There were a total of 5,508 data points collected.

Training Session

Before the experiment each subject was given a 10–20 minute practice session. The subjects were allowed to get familiar with the grocery items, cameras and scanning table.

Experimental Design

The 17 independent variables that contributed to wrist deviations in this experiment consisted of grocery items. Each of the 17 grocery items used in this experiment were from one of four different categories: canned, boxed, bottle and flexible products. These four categories constitute 76% of all items scanned by a checker during a normal working shift (21).

The three dependent measurements in this study included mean, maximum and minimum of wrist angular acceleration, angular velocity and position in three planes: (a)

radial/ulnar (see Figure 3), (b) flexion/extension (see Figures 4, 5, and 6), and (c) pronation/supination (see Figure 7).

The means of the variables are defined in three phases:

1. The subject picks up the grocery item and starts the "scanning motion."
2. The subject does the repetitive scanning motion back and forth until a "beeping sound" is heard.
3. The subject places the item at the end of the table with the left hand.

The subject was required to scan all items within a time frame of 15 minutes during a 1-hour time period. During the first 2 minutes of the beginning trial and ending trial the motion was recorded by eight cameras. The calibrations of the eight cameras were performed prior to the initial experiment. A photo of the scanning table and the octagon system of video cameras is shown in Figure 9. The two dimensional views of the eight cameras were transformed into a three-dimensional view of five markers.

The subjects had a total of five reflector markers placed on their left hand, elbow and wrist. Marker 1 was placed on the proximal third phalange, marker 2 was placed on the medial wrist, marker 3 was place on the lateral wrist, marker 4 was placed on the lateral elbow, and marker 5 was place on the medial ulnar.

The subjects scanned 17 grocery items in a random order while data were collected. Each subject scanned an item across a table until a beep was heard. Once the beep was heard the subject placed the item at the end of the table with his/her left hand. The subject continued this protocol until all items were scanned. The subjects scanned the 17 items for 15 minutes per hour for the next 4 hours. The time limit of 15 minutes was chosen so the subject could scan the items to exhaustion in the given time period. The subjects scanned an average of 558 items in 15 minutes, which is comparable to an

average checker scanning rate in 1 hour (35). During the first part of the experiment the subject's left wrist, hand and forearm were videotaped and digitized on the Peak–Motus camera system.

During the interim period between the beginning and the end of the experiment no data were collected. During the last part of the experiment data were recorded and the grocery items were scanned multiple times in a random order for 15 minutes.

Figure 4: Flexion/extension

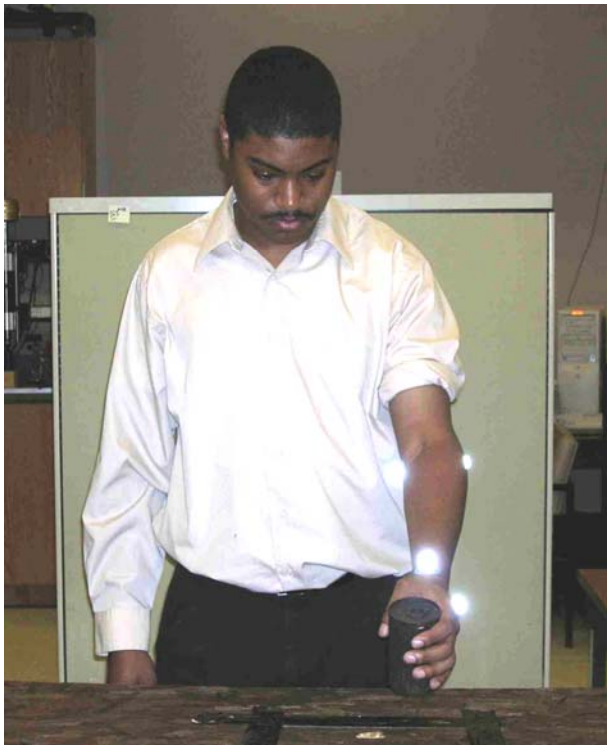

Figure 5: Flexion/extension—subject in neutral plane with four of five markers visible

Figure 6: Flexion/extension—subject in extension plane with four of five markers visible

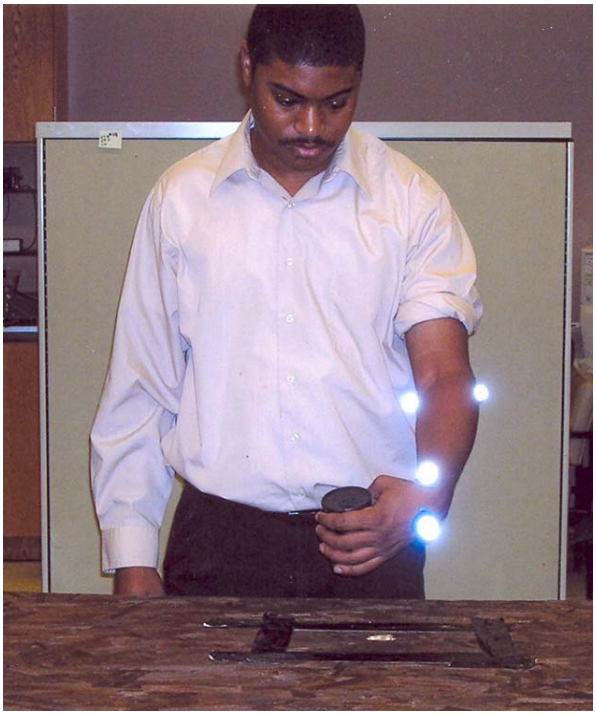

Figure 7: Flexion/extension—subject in flexion plane with four of five markers visible

Figure 8: Pronation/supination plane

Figure 9: Scanning table and eight octagon camera system with seven cameras visible

CHAPTER FOUR: RESULTS

A total of 5,508 observations were collected from 17 kinematic variables across three planes from the hand, wrist and elbow. The data collected consisted of: 9 subjects, 17 grocery items, 3 groups (acceleration, velocity and position), 6 minimum and maximum points within the 3 planes (radial/ulnar, flexion/extension, pronation/ supination) and 2 intervals at the beginning and end of scanning (see Tables 8–13 in the Appendix). The mean, maximum and minimum of wrist angular acceleration, angular velocity and position is shown in Table 3.

These data were compared to the wrist industries standard data by Marras and Schoenmarklin (22). The statistical analysis consisted of carrying out t tests of the relevant hypothesis using SAS software (29). A paired t test was performed to analyze

Table 3: Measurements of the mean, maximum and minimum of wrist angular acceleration, angular velocity and position in three planes

	Radial/Ulnar			Flexion/Extension			Pronation/Supination		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Velocity (Deg/Sec)									
H.R. Mean	25.9	-115.1	115.7	42.2	-183.7	174.2	91.3	-403.2	449.2
H.R. S.D.	6.7	36.5	39.5	11.7	76.8	58.4	23.3	149.1	256.2
L.R. Mean	17	-79.3	77.3	28.7	-121.2	120.3	67.7	-289.9	300.2
L.R. S.D.	6.7	34.9	31.1	7.6	42.8	38.1	19.5	112	129
Acceleration (Deg/Sec^2)									
H.R. Mean	494	-2776	3077	824	-4927	4471	1824	-11987	11291
H.R. S.D.	142	913	1313	268	1913	1527	533	6330	4954
L.R. Mean	301	-1755	1759	494	-2788	2588	1222	-6811	7169
L.R. S.D.	125	818	834	156	862	802	384	2571	2980
Position (Degrees)									
H.R.Mean	-6.73	-18.96	4.69	-12.02	-29.08	6.56	8.3	-38.93	47.7
H.R. S.D.	4.66	5.78	4.76	7.16	7.32	11.11	20.5	23.4	19.48
L.R. Mean	-7.62	-16.51	1.12	-10.09	-23.58	4.35	2.47	-31.84	37.36
L.R. S.D.	4.42	5.57	6.17	11.88	13.12	12.36	38.63	38.76	38.69

the beginning and end effects of scanning 17 grocery items in three planes from the start of the experiment until the end during a 4-hour period. An independent t test was used to compare the mean values of the wrist data to the industry standard means. Acceleration, velocity and position variables were analyzed from each subject as a predictor of high risk to CTDs. Finally a comparison of the subjects' mean height, weight and BMI as a predictor for CTDs were analyzed.

A measured observation in this study that was at or above the low risk mean of the industry standards data by Marras and Schoenmarklin (22) was considered to be a strong predictor for CTDs/CTS risk. Of all the kinematic variables included in the analyses we found that the acceleration flexion/extension plane is the strongest predictor of CTDs in the scanning group. The flexion/extension plane also produced the most observations of low risk CTDs in the velocity and position group. The pronation/ supination groups measured CTDs observations in the velocity group with 39 results that were equal to or greater than the low risk means of Marras and Schoenmarklin's (22) industry standard data (see Appendix Tables 8–13).

A paired t test was used to test the null hypothesis that the average of the differences used to test the null hypothesis of scanning before and after produces a mean of zero. Hypothesis Ho: $m1 - m2 = 0$; 4 hours of scanning produces no measurements of CTDs. Alternative hypothesis Ha: $m1 - m2 \neq 0$ 4 hours of scanning does produce measurements of CTDs. The overall paired t test statistics of analyzing wrist motion measurements of before and after scanning grocery items as a function of low risk CTDs are shown in Tables 4–6.

The statistical measurements in Table 4 show the overall group risk mean of the before and after scanning effects for acceleration. The planes in the acceleration group consisted of flexion/extension, radial/ulnar, and pronation/supination. For the flexion/extension plane a mean difference of -100.94 ($p = 0.25$) and a 95% confidence interval of -216.99 to 14.21 was reported (Figure 10). For the radial/ulnar plane a mean difference of -43.55 ($p = 0.001$) and a 95% confidence interval of -67.36 to -19.74 was reported. For the pronation/supination plane a mean difference of 2.33 ($p = 0.02$) and a 95% confidence interval of 0.30 to 4.36 was reported. Seeing as the p values for the radial/ulnar and pronation/supination planes were less than the alpha level of 0.05, we accepted the null hypothesis that scanning after 4 hours produces no measurements of CTDs in these two planes. However, for the flexion/extension plane, because the p value was 0.25, which is greater than the alpha level of 0.05, we rejected the null hypothesis and accepted the alternative that scanning does produces CTDs over a 4-hour period in this plane.

Table 4: Analysis of group mean differences for acceleration between control test begin (CTB) and control test end (CTE) of scanning grocery items after a 4-hour time period at the $\alpha = 0.5$ level

				Confidence Level for Mean	
	Mean	Std. Dev.	Std. Error	Lower 95%	Upper 95%
Flexion/Extension t value = -1.85 p = 0.25	-100.94	231.56	54.58	-216.99	14.21
Radial/Ulnar t value = -3.86 p = 0.001	-43.55	47.87	11.28	-67.36	-19.74
Pronation/Supination t value = 2.42 p = 0.02	2.33	4.08	0.96	0.300	4.36

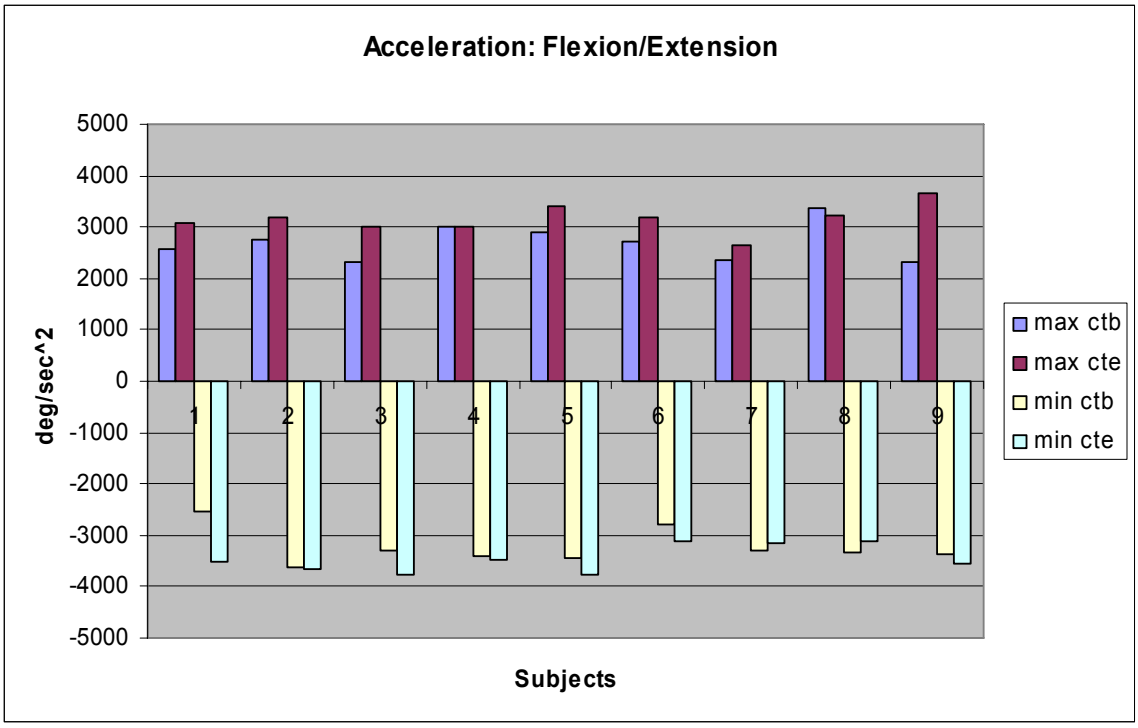

Figure 10: Acceleration: Flexion/Extension results
Note: max ctb = maximum control test begin; max cte = maximum control test end; min ctb = minimum control test begin; min cte = minimum control test end

For velocity the mean difference between beginning and end of scanning for flexion/extension plane was 2.33 with t value of 2.42, p = 0.02 and a confidence interval of 1.24 to 4.36 (Table 5). For the radial/ulnar plane the mean difference was -3.44 with a t value of -5.36, p = 0.001, and a confidence interval of -4.80 to -2.08. For the pronation/supination plane there was a mean difference of -0.27 with a t value of -0.14, and p = 0.88 (Figure 11). Because the flexion/extension and radial/ulnar plane each had differences with a p value less than 0.05 we concluded that for these factors there is no significant difference in CTDs in scanning over time. However, with a p value of 0.88 we concluded that there was a significant difference for velocity in the pronation/supination plane.

Table 5: Analysis of group mean differences for velocity between Control Test Begin (CTB) and Control Test End (CTE) of scanning grocery items after a 4-hour time period at the $\alpha = 0.5$ level

				Confidence Level for Mean	
	Mean	Std. Dev.	Std. Error	Lower 95%	Upper 95%
Flexion/Extension t = 2.42 p = 0.02	2.33	4.08	0.96	1.24	4.36
Radial/Ulnar t value = -.5.36 p = 0.0001	-3.44	2.72	0.64	-4.80	-2.08
Pronation/Supination t value = -.014 p = 0.88	-0.27	8.23	1.94	-4.37	3.81

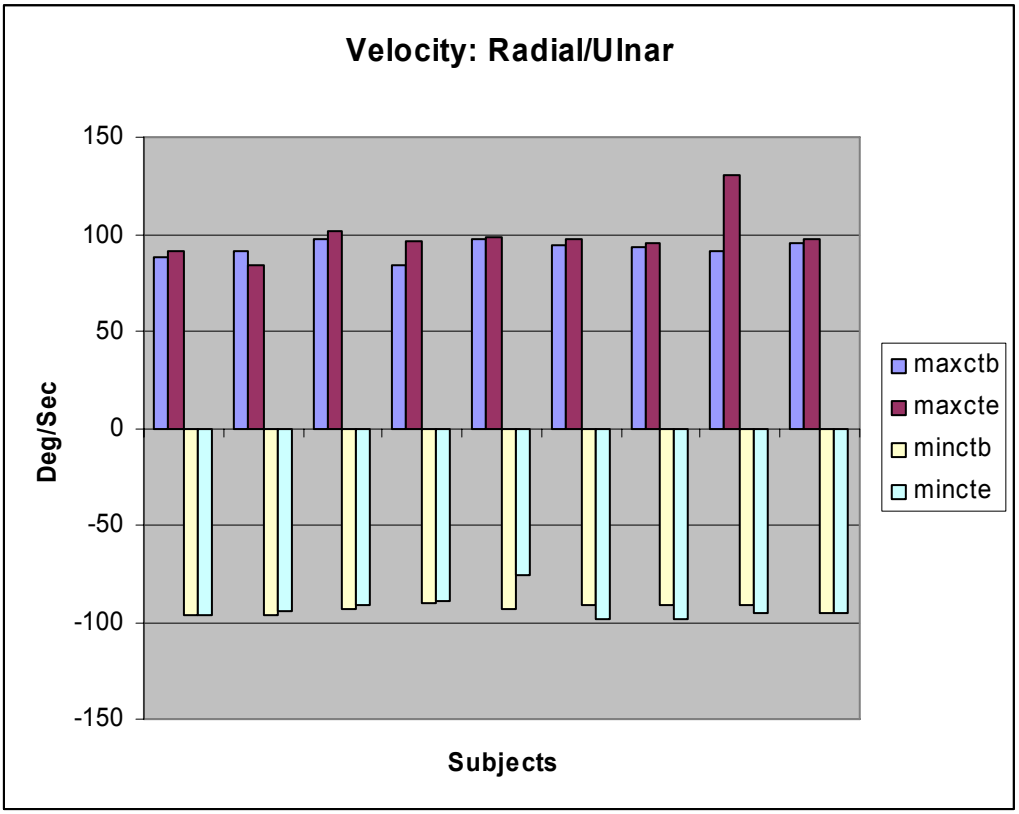

Figure 11: Velocity: Radial/Ulnar results
Note: maxctb = maximum control test begin; maxcte = maximum control test end; minctb = minimum control test begin; mincte = minimum control test end

For position, the flexion/extension and radial/ulnar mean differences had p values less than 0.05 indicating no significant mean difference in the end and beginning of scanning trial of CTDs. For position, the mean difference for the flexion/extension plane was 0.69 with a t value of -3.75, p = 0.001, and a confidence interval of -1.07 to -0.30. The p value of the pronation/supination plane was 0.02, less than the alpha level of 0.05 (Figure 11). Therefore we accept the null hypothesis that there is no difference in scanning trial of CTD's in this plane. The reported values are shown in Table 6.

Tables 8–13 in Appendix A show 248 variables for acceleration, 147 variables for velocity, and 67 variables for position. The reported variables are considered to be the minimum low risk in the left hand for cumulative trauma disorders.

An independent sample t test was used to test the hypothesis that the difference between the means of two samples is equal to 0. This was conducted to see if there was any difference in low risk mean benchmark values versus scanning values. Table 7 reports a calculated t value of 0.81 and 0.71 in the beginning and end group, respectively, against a critical t value of 1.74. This indicates that the scanning group exhibits low risk cumulative trauma disorders that may lead to CTS in the flexion/extension plane of the acceleration group. The velocity and position group means do not equal the low risk standard benchmark means of Marras and Schoenmarklin (22). The flexion/extension values in the acceleration group in this experiment are our best evidence that scanning can cause employees CTDs that may lead to CTS over a four hour period of time.

Table 6: Analysis of group mean differences for position between control test begin (CTB) and control test end (CTE) of scanning grocery items after a 4-hour time period at the $\alpha = 0.5$ level

				Confidence Level for Mean	
	Mean	Std. Dev.	Std. Error	Lower 95%	Upper 95%
Flexion/Extension t = -3.75 p = 0.001	-0.69	0.78	0.18	-1.07	-0.30
Radial/Ulnar t value = -1.99 p = 0.06	-0.08	0.18	0.04	-0.18	0.005
Pronation/Supination t value = -2.45 p = 0.02	-0.76	1.31	0.31	-1.41	-0.10

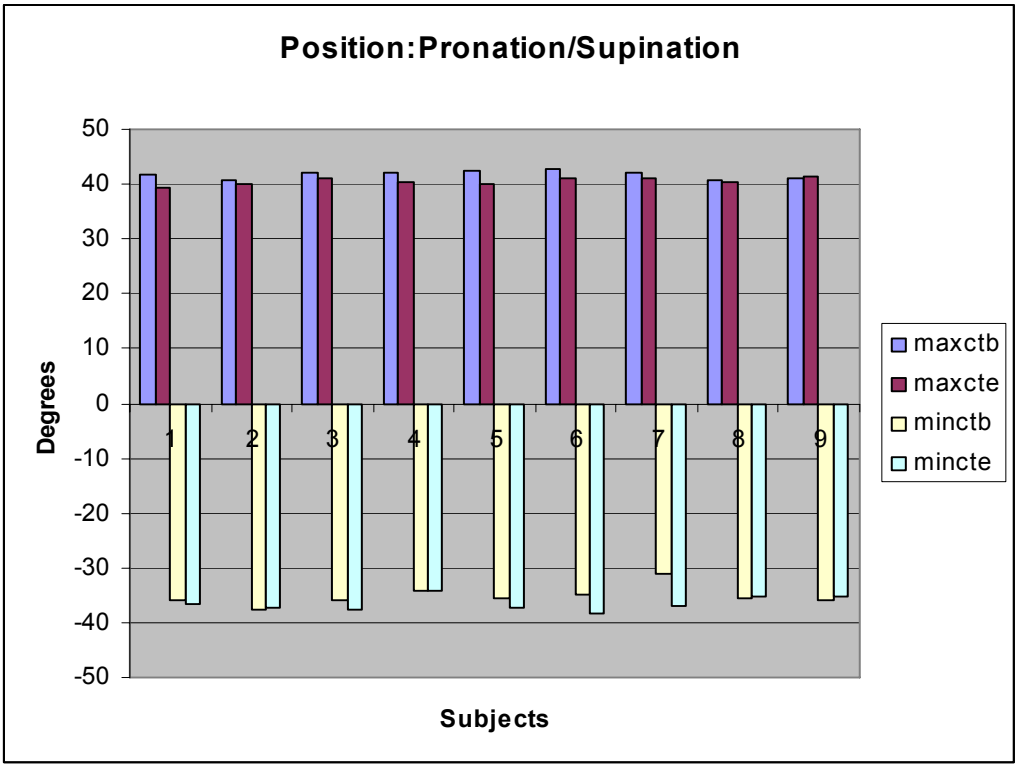

Figure 12: Position: Pronation/supination results
Note: maxctb = maximum control test begin; maxcte = maximum control test end; minctb = minimum control test begin; mincte = minimum control test end

Table 7: t test comparison of group means in three planes

	Flexion/Extension		Pronate/Supination		Radial/Ulnar	
	TB	TE	TB	TE	TB	TE
Acceleration						
tcal	0.81	0.71	4.29	4.01	3.68	3.48
tcrit	1.74	1.74	1.74	1.74	1.74	1.74
Velocity						
tcal	9.203	4.46	7.99	7.87	7.69	8.07
tcrit	1.74	1.74	1.74	1.74	1.74	1.74
Position						
tcal	3.33	4.34	11.97	11.34	3.35	3.33
tcrit	1.74	1.74	1.74	1.74	1.74	1.74

CHAPTER FIVE: DISCUSSION

Statistical Significance and Interpretations

The expectation of this study was to find how much scanning contributes to cumulative trauma disorders that may lead to carpal tunnel syndrome. The study provides evidence that scanning after a 4-hour period with the left hand increases the risk of developing CTDs in the flexion/extension plane during acceleration. There was a 2 to 1 ratio of low risk CTDs kinematic variables reported during the first phases of the trial compared to the last phase. All subjects in each group reported an increase in CTDs during this experiment. The statistical analysis used in this study was a paired difference t test, which compared the measurements of the beginning scanning of grocery items to those at the ending of scanning grocery items after a 4-hour time period. Although this experiment provided evidence of CTDs resulting from scanning, a multivariate technique statistical technique could have been used to determine which motion variables were the best predictors of hand and wrist incidence rate. This technique could have helped in summarizing the data and reducing the number of variables in describing this experiment and provided a better confidence interval than the paired t test. For instance, comparing the type of grocery items (can, boxed, and flexible) being scanned to the various planes (radial/ulnar, flexion/extension, pronation/supination) of the wrist position during the scanning procedure. scanning.

There were 462 of 5,508 variables found to be at low risk for CTDs in the left hand during scanning. Female checkers (subjects C1, C3, C8) reported the highest variables in all three planes. According to the literature (33) smaller wrist size in the female participants may contribute to their chances of developing CTS. There was no

positive correlation of CTDs with height, BMI or age in this study. In spite of the small number of subjects studied there is ample evidence that scanning can lead to CTS based on the nature of repetitive wrist motion that requires handling different sized objects. Some of the problems encountered at the scanning workstations include reaching and overreaching above the shoulder level, lifting and rotating heavy items and multiple grasping motions while identifying the scanning barcode.

Recommendations

Further research in this area should include a study within a natural work setting (grocery store). Food items should be studied by category and compared independently to track which items contribute the most in CTDs/CTS. Ergonomic improvement in the check stand should be studied to eliminate chances of musculoskeletal disorders in this environment. A better method of placing scanning bar codes should be used to eliminate multiple rotation and heavy lifting. Braces on the workers' wrists to discriminate against the range of motions and different paces of scanning grocery items as it relates to CTDs/CTS should be compared and contrasted. The results of this study could aid ergonomic professionals in assessing equipment and people hazards with regards to repetitive hand/wrist motion in grocery and scanning occupations.

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APPENDIX A: DATA TABLES

Table 8: Control test begin, subjects 1-9: Acceleration (units :deg/sec^2)

subject	accl	item	max flex	min flex	max pro	min pro	max rad	min rad
c1	t1	1	4516	-2215	7421	-6562	1687	-1711
		2	2399	-2750	6821	-6317	1754	-1620
		3	1311	-2331	6632	-6587	1804	-1755
		4	2400	-2665	7462	-7461	1733	-1706
		5	4011	-2424	7352	-6722	1814	-1579
		6	2571	-2168	6477	-6953	1981	-1625
		7	3461	-2256	8361	-5526	2001	-1830
		8	1999	-2126	6215	-5526	1633	-1779
		9	3205	-2615	6522	-6461	1878	-1715
		10	3510	-2354	7377	-5461	1776	-1651
		11	1431	-2415	6988	-5785	1691	-1755
		12	2325	-2561	7221	-5786	1611	-1698
		13	1651	-2690	7177	-5956	1701	-1778
		14	2001	-1885	7710	-6963	1556	-1555
		15	2851	-2365	6915	-5521	1764	-1944
		16	2211	-2154	7649	-6521	1698	-1551
		17	1765	-2161	6322	-5226	1777	-2101
		SUM	43618	-40135	120622	-105334	29859	-29353
		MEAN	2565.76	-2360.80	7095.41	-6196.1	1756.41	-1726.60
c2	t1	1	1985	-1877	5955	-4665	1956	-1672
		2	2216	-2012	6215	-5564	2025	-1557
		3	2315	-2651	6379	-6001	1650	-1598
		4	2254	-2115	6965	-4751	1525	-1487
		5	2431	-2196	6001	-5978	1662	-1431
		6	2315	-2001	6875	-5897	1478	-1550
		7	2115	-2246	6965	-6116	1322	-1638
		8	2261	-2011	6464	-6161	1407	-1713
		9	1986	-2255	6388	-7198	2105	-1557
		10	2865	-2044	6445	-5998	1669	-1699
		11	2461	-1986	6421	-6751	1678	-1701
		12	2351	-2332	6621	-6846	1498	-1655
		13	2421	-2115	6559	-5925	1752	-1446
		14	2001	-2385	6112	-6750	1954	-2566
		15	2575	-1878	6422	-4656	1611	-2235
		16	2651	-2155	6336	-5811	1814	-1833
		17	2422	-2551	6107	-5789	1712	-1660
		SUM	39625	-36810	109230	-100857	28818	-28998
		MEAN	2330.88	-2165.20	6425.29	-5932.70	1695.17	-1705.70
c3	t1	1	2611	-2211	8325	-6603	1754	-1776
		2	2156	-2315	6338	-6750	1544	-1552
		3	2851	-2465	7489	-6432	1698	-1479
		4	3371	-2617	7065	-6898	1801	-1677
		5	2652	-2715	8641	-5116	1769	-1755

			6	2251	-2819	7459	-6988	1755	-1612
			7	2369	-2013	6448	-5751	1305	-1806
			8	1989	-2351	6467	-5236	1611	-1631
			9	1777	-2255	6556	-6789	1256	-1622
			10	2705	-2695	6351	-5521	1149	-1777
			11	2235	-2786	6325	-6751	1350	-1413
			12	1995	-2056	7005	-6785	1251	-1489
			13	2678	-2335	6199	-5541	1368	-1365
			14	1859	-2799	6329	-6526	1497	-1246
			15	2417	-2219	6612	-6001	1511	-1136
			16	2316	-2561	6468	-7321	1591	-1255
			17	2251	-2455	6379	-5689	1687	-1622
				2588	-2788	6779	-6811	1759	-1455
		SUM		40483	-41667	116456	-106698	25897	-26213
		MEAN		2381.35	-2451	6850.35	-6276.3	1523.35	-1541.90
c4	t1		1	2315	-1824	7255	-5669	1566	-1435
			2	2611	-1722	7001	-4750	1654	-1453
			3	2461	-1725	7412	-5546	1578	-1596
			4	1878	-1630	6082	-5119	1690	-1675
			5	2119	-2441	6378	-6652	1533	-1601
			6	2367	-2569	6365	-6849	1702	-1552
			7	1955	-2655	6889	-6471	1536	-1595
			8	2005	-2652	6442	-6564	1425	-1321
			9	2615	-2679	6369	-6789	1312	-1411
			10	2078	-2421	6995	-5521	1289	-1479
			11	1815	-2868	6816	-6001	1320	-1578
			12	1667	-2759	7188	-5897	1401	-1589
			13	2216	-2431	6446	-7215	1710	-1534
			14	2561	-2856	6475	-7214	1435	-1512
			15	2322	-2002	6551	-6822	1581	-1436
			16	2478	-2611	6633	-6471	1565	-1455
			17	2629	-2881	6897	-6566	1687	-1399
		SUM		38092	-40726	114194	-106116	25984	-25621
		MEAN		2240.70	-2395.60	6717.29	-6242.10	1528.47	-1507.11
c5	t1		1	2250	-2141	6416	-6689	1728	-1635
			2	2251	-2009	6825	-6651	1724	-1652
			3	2312	-2310	6438	-5546	1711	-1679
			4	2256	-2366	7356	-6349	1669	-1675
			5	2278	-2431	6521	-5116	1685	-1601
			6	2011	-2515	6874	-5897	1621	-1655
			7	1852	-2335	6366	-6751	1560	-1721
			8	2089	-2779	6621	-6177	1609	-1762
			9	2488	-2565	6871	-6105	1712	-1774
			10	2115	-2010	7322	-5521	1589	-1769
			11	2216	-2211	6465	-6955	1550	-1578
			12	2422	-2669	6998	-5785	1401	-1588
			13	2511	-2614	7214	-5461	1682	-1565

			14	2611	-2766	6445	-5526	1735	-1718
			15	2261	-2651	6362	-6792	1581	-1652
			16	2598	-2315	5874	-6461	1665	-1655
			17	2315	-2105	6961	-6522	1687	-1710
		SUM		38836	-40792	113929	-104304	27909	-28389
		MEAN		2284.47	-2399.51	6701.70	-6135.52	1641.70	-1669.91
c6	t1		1	2488	-2356	7105	-6650	1518	-1636
			2	2213	-2216	6717	-5752	1652	-1773
			3	1987	-2446	6466	-6116	1679	-1789
			4	2659	-2310	6311	-7198	1401	-1744
			5	2325	-2446	6792	-6461	1751	-1675
			6	1898	-2089	6701	-5258	1857	-1701
			7	1756	-2926	6691	-5661	1555	-1687
			8	2232	-2433	6215	-6351	1687	-1699
			9	2425	-2411	6356	-6211	1512	-1668
			10	2689	-2365	7998	-6521	1676	-1564
			11	2516	-2468	7336	-5956	1550	-1565
			12	2251	-2415	6425	-5885	1401	-1511
			13	2471	-2615	7889	-6463	1474	-1461
			14	2519	-2781	6844	-6526	1550	-1422
			15	2250	-2051	6737	-6701	1557	-1535
			16	2489	-2961	6362	-5899	1688	-1697
			17	2425	-2655	6656	-6105	1620	-1701
		SUM		39593	-41944	115601	-105714	27128	-27828
		MEAN		2329	-2467.2	6800.059	-6218.4	1595.765	-1636.9
c7	c1		1	2256	-2661	7149	-6056	1599	-1639
			2	2379	-2556	7377	-6799	1667	-1711
			3	2546	-2756	6520	-6554	1688	-1746
			4	2289	-2256	7161	-6736	1690	-1741
			5	2103	-2154	6951	-6803	1761	-1679
			6	2115	-2683	6789	-6256	1712	-1702
			7	2348	-2556	6752	-6395	1615	-1656
			8	2585	-2442	7105	-7641	1687	-1685
			9	1878	-2604	6963	-5798	1525	-1671
			10	2516	-2818	7113	-6521	1689	-1722
			11	2115	-2256	7268	-5956	1650	-1789
			12	2615	-2312	6950	-6785	1702	-1769
			13	2250	-2661	6652	-6461	1601	-1655
			14	2447	-2516	6769	-6526	1745	-1612
			15	2314	-2817	7105	-6399	1523	-1461
			16	2569	-2955	6745	-7025	1565	-1655
			17	2436	-2878	6622	-6911	1686	-1568
		SUM		39761	-43881	117991	-111622	28105	-28461
		MEAN		2338.88	-2581.21	6940.64	-6566	1653.23	-1674.1

c8	t1		1	2665	-2611	7069	-6850	1611	-1702
			2	2376	-2362	6521	-6622	1554	-1878
			3	2315	-2515	6821	-6956	1478	-1616
			4	2592	-2667	6964	-6113	1496	-1752
			5	2534	-2612	6851	-6221	1585	-1699
			6	2617	-2291	6879	-6879	1614	-1707
			7	2445	-2356	7605	-6889	1701	-1698
			8	2532	-2717	7332	-5589	1698	-1765
			9	2489	-2665	7052	-6789	1616	-1501
			10	2486	-2431	6999	-6521	1585	-1596
			11	2578	-2515	7105	-6802	1756	-1722
			12	2315	-2602	6567	-6785	1801	-1746
			13	2365	-2467	6471	-6432	1659	-1631
			14	2401	-2554	6671	-6555	1722	-1579
			15	2315	-2468	7105	-6332	1564	-1438
			16	2609	-2544	7002	-6961	1822	-1601
			17	2612	-2723	6516	-6877	1733	-1588
		SUM		42246	-43100	117530	-112173	27995	-28219
		MEAN		2485.05	-2535.23	6913.52	-6598.42	1646.76	-1659.91
c9	t1		1	2385	-2611	6265	-6113	1718	-1699
			2	2345	-2312	7006	-6223	1754	-1701
			3	2215	-2489	6678	-6447	1678	-1744
			4	2678	-2065	7133	-6623	1690	-1722
			5	1951	-2178	6799	-6223	1551	-1726
			6	1815	-2489	6806	-6433	1582	-1694
			7	2089	-2651	6832	-6474	1650	-1633
			8	2215	-2325	6365	-6564	1725	-1621
			9	2364	-2489	7152	-6789	1614	-1583
			10	2854	-2356	7001	-6521	1571	-1511
			11	1818	-2859	6689	-6566	1599	-1599
			12	1609	-2688	6950	-6112	1587	-1653
			13	2203	-2654	6651	-6463	1659	-1622
			14	2416	-2769	6532	-6992	1625	-1699
			15	2518	-2855	6791	-6332	1671	-1756
			16	2616	-2561	6726	-6461	1665	-1745
			17	2550	-2664	6516	-6113	1727	-1698
		SUM		41229	-43015	114892	-109449	28066	-28406
		MEAN		2425.23	-2530.22	6758.35	-6438.15	1650.94	-1670.92
				2588	-2788	7169	-6811	1759	-1755
C1-C9	TOTAL	SUM		363483	-372070	1040445	-962267	249761	-251488
	TOTAL	MEAN		2375.70	-2431.82	6800.29	-6289.30	1632.42	-1643.72
	BENCHMARK			2588	-2788	7169	-6811	1759	-1755
	accel. 1			max flex	min flex	Max pro	min pro	max rad	min rad

Table 9: Control test end, subjects 1-9: Acceleration (units: deg/sec^2)

subject	accl	item	Max flex	min flex	max pro	min pro	max rad	min rad
c1	t2	1	2251	-2432	7661	-6015	2213	-1855
		2	2659	-2555	7122	-6788	2215	-1616
		3	2761	-2464	6981	-6501	1761	-1751
		4	2332	-2877	7654	-6325	2311	-1633
		5	2886	-2461	7115	-6725	1701	-1751
		6	2661	-2697	7223	-6887	1522	-1697
		7	2625	-2316	7715	-6955	1744	-1803
		8	2216	-2554	6470	-6709	1944	-1752
		9	2214	-2615	7722	-6713	1825	-1754
		10	2744	-2877	6731	-6791	1743	-1824
		11	2211	-2571	7689	-6522	1611	-1951
		12	2387	-3164	7016	-6785	1723	-1697
		13	2618	-2862	7321	-6665	1679	-1655
		14	2861	-2001	6987	-6802	1644	-1716
		15	2449	-2612	6964	-6575	1951	-1885
		16	2361	-3346	6653	-6722	1707	-1911
		17	2601	-2652	7421	-6755	1679	-1692
		SUM	42837	-45056	122445	-113235	30973	-29943
		MEAN	2519.82	-2650.32	7202.64	-6660.82	1821.94	-1761.32
c2	t2	1	2611	-2670	6536	7398	2008	-1501
		2	2155	-2256	7795	-7119	1805	-1622
		3	2321	-2369	6365	-6079	1706	-1467
		4	2112	-2762	6217	-6319	1613	-1566
		5	1991	-1811	5819	-6752	1651	-1722
		6	2215	-1609	5879	-6754	1654	-1687
		7	2341	-2256	7226	-6766	1722	-1623
		8	2896	-1731	7001	-6512	1633	-1513
		9	2911	-2654	6952	-6789	1566	-1602
		10	2169	-2188	7005	-6532	1729	-1547
		11	2216	-2179	7129	-6764	1701	-1587
		12	2578	-2261	6995	-6557	1654	-1576
		13	2746	-2235	6961	-6211	1677	-1819
		14	2849	-2016	6466	-6591	1561	-1706
		15	2734	-1911	6443	-6110	1717	-1785
		16	2898	-1877	6125	-5433	1672	-1855
		17	2077	-1662	6651	-5822	1666	-1956
		SUM	41820	-36447	113565	-95712	28735	-28134
		MEAN	2460	-2143.93	6680.29	-5630.1	1690.29	-1654.91
c3	t2	1	2255	-3008	6532	-7035	1606	-1641
		2	2252	-2312	7952	-6871	1813	-1725
		3	2514	-2581	8115	-6556	1777	-1379
		4	1878	-2610	6951	-6771	1699	-1487
		5	2269	-2715	6852	-6267	1689	-1671
		6	2499	-2665	6879	-6998	1647	-1521
		7	2315	-2325	7266	-5233	1475	-1791

			8	2398	-2711	6465	-5564	2025	-1451
			9	2263	-2416	6953	-5778	1596	-1555
			10	2001	-2556	7232	-6113	1447	-1671
			11	2256	-2575	7109	-6122	1552	-1478
			12	2275	-2651	6781	-7088	2261	-1490
			13	2816	-2633	6952	-5711	1459	-1381
			14	2499	-3156	7477	-6433	1649	-1965
			15	2651	-2597	7216	-6922	1672	-1685
			16	2379	-2697	6561	-6961	1561	-1746
			17	2015	-2614	7543	-5785	1722	-1655
		SUM		39535	-44822	120836	-108208	28650	-27292
		MEAN		2325.58	-2636.52	7108	-6365.15	1685.29	-1605.41
c4	t2		1	2477	-2655	6965	-7011	1461	-1425
			2	2235	-2312	6876	-6750	1504	-1752
			3	2365	-2802	7119	-6253	1278	-1679
			4	2689	-2887	6964	-7066	1690	-1675
			5	2581	-2525	6851	-6112	1751	-1410
			6	2701	-2605	6879	-6977	1801	-1566
			7	2665	-2504	7020	-6751	1615	-1701
			8	3001	-2668	6468	-6464	1405	-1851
			9	1989	-2956	7252	-6789	1512	-1422
			10	2578	-2010	7132	-6213	1589	-1691
			11	2459	-2889	6689	-6733	1415	-1587
			12	2119	-2298	6950	-6771	1422	-1636
			13	2554	-2436	7031	-6468	1769	-1611
			14	2398	-2779	6446	-6119	1521	-1622
			15	3661	-2718	6515	-6223	1422	-1735
			16	2526	-2669	6798	-7022	1655	-1655
			17	2256	-2616	6462	-6186	1671	-1758
		SUM		43254	-44329	116417	-111908	26481	-27776
		MEAN		2544.35	-2607.53	6848.05	-6582.82	1557.706	-1633.81
c5	t2		1	2889	-3006	6332	-6952	1854	-1735
			2	2975	-3189	6868	-6225	1813	-1651
			3	2351	-2811	6219	-7446	1648	-1662
			4	2680	-2424	7964	-6326	1685	-1653
			5	2446	-2786	7184	-6566	1691	-1711
			6	2215	-2305	6296	-6976	1651	-1844
			7	2589	-2656	6334	-6668	1722	-1642
			8	2489	-2565	6465	-6435	1625	-1651
			9	2697	-2688	6952	-6802	1655	-1665
			10	2256	-2699	7001	-6421	1801	-1756
			11	3216	-2522	6761	-6894	1667	-1722
			12	2497	-2668	6986	-6758	1702	-1688
			13	2011	-2315	6651	-6339	1535	-1766
			14	2577	-2677	6422	-6526	1435	-1697
			15	2488	-2889	6502	-6791	1684	-1841
			16	2156	-3151	7330	-6466	1575	-1725

			17	2489	-2615	7369	-6523	1664	-1899
			SUM	43021	-45966	115636	-113114	28407	-29308
			MEAN	2530.64	-2703.82	6802.11	-6653.71	1671.01	-1724.22
c6	t2		1	2426	-2790	6256	-6479	1688	-1701
			2	2525	-2655	7187	-6336	1654	-1798
			3	2216	-2699	7522	-6226	1701	-1761
			4	2555	-2665	6263	-6694	1622	-1675
			5	2616	-2688	6851	-6116	1582	-1722
			6	2355	-2652	6878	-6487	1701	-1650
			7	2426	-2755	7152	-6522	1653	-1722
			8	2611	-2811	6165	-6020	1717	-1633
			9	2219	-2744	6299	-6511	1786	-1525
			10	2664	-2658	8103	-6386	1744	-1601
			11	2315	-2798	7680	-6911	1652	-1678
			12	2101	-2699	6956	-6781	1661	-1689
			13	2006	-2688	6695	-6568	1676	-1695
			14	2305	-2692	7069	-6777	1654	-1633
			15	2565	-2792	6501	-6391	1721	-1599
			16	2489	-2864	6441	-6422	1741	-1722
			17	2288	-2779	7002	-7002	1657	-1785
			SUM	40682	-46429	117020	-110629	28610	-28589
			MEAN	2393.05	-2731.15	6883.52	-6507.53	1682.94	-1681.72
c7	t2		1	2275	-2552	6865	-6721	1681	-1701
			2	2475	-2678	7122	-6750	1655	-1699
			3	2465	-2644	7199	-6651	1647	-1587
			4	2656	-2553	6961	-6787	1590	-1699
			5	2285	-2651	6861	-7911	1755	-1711
			6	2813	-2699	8877	-6050	1815	-1758
			7	2685	-2435	6266	-6785	1711	-1761
			8	2768	-2598	6863	-6921	1699	-1764
			9	1815	-2661	6952	-6897	1714	-1732
			10	2236	-2756	6756	-6402	1698	-1705
			11	2110	-2561	6891	-6333	1660	-1789
			12	2432	-2652	6995	-6020	1679	-1688
			13	2275	-2546	6961	-6422	1688	-1671
			14	2214	-2698	7469	-6762	1697	-1702
			15	2219	-2462	6750	-6523	1747	-1693
			16	2519	-2518	6661	-6771	1722	-1706
			17	2415	-3217	7101	-7611	1789	-1755
			SUM	40657	-44881	119550	-114317	28947	-29121
			MEAN	2391.58	-2640.07	7032.35	-6724.52	1702.765	-1713.31
c8	t2		1	2497	-2688	7779	-6433	1511	-1640
			2	2698	-2722	7668	-6952	1579	-1675
			3	2566	-2893	7223	-7101	1651	-1679
			4	2489	-2765	6964	-6461	1714	-1555
			5	2655	-2689	6865	-6561	1778	-1671

			6	2652	-2610	7879	-6651	1765	-1735
			7	2701	-2556	6821	-6332	1655	-1755
			8	2569	-2819	6564	-6856	1644	-1711
			9	2416	-2852	6852	-6789	1812	-1758
			10	2641	-2755	6632	-7001	1761	-1676
			11	2456	-2816	6877	-6994	1701	-1822
			12	2751	-2632	7125	-6779	1699	-1689
			13	2467	-2655	7365	-6561	1655	-1701
			14	2461	-2733	7002	-5856	1722	-1728
			15	2643	-2721	7446	-7002	1733	-1699
			16	2871	-2866	7522	-6877	1665	-1722
			17	2622	-2711	6998	-6922	1722	-1747
		SUM		44155	-46483	121582	-114128	28767	-28963
		MEAN		2597.35	-2734.20	7151.88	-6713.43	1692.17	-1703.72
c9	t2		1	2668	-2522	7105	-6663	1683	-1722
			2	2319	-2455	7112	-6976	1688	-1699
			3	2575	-2791	7332	-7112	1677	-1687
			4	2351	-2664	6995	-6877	1691	-1721
			5	2561	-2652	6652	-6653	1676	-1731
			6	2625	-2725	6875	-6597	1621	-1697
			7	2611	-2795	7007	-6677	1650	-1685
			8	2595	-2822	6895	-6725	1715	-1632
			9	2415	-2601	6851	-6799	1665	-1656
			10	2522	-2533	6732	-6521	1757	-1721
			11	2488	-2561	6788	-7127	1688	-1733
			12	2325	-2599	6952	-6692	1699	-1765
			13	2632	-2625	6446	-6623	1722	-1721
			14	2516	-2575	6977	-6562	1666	-1698
			15	2461	-2545	6563	-6559	1659	-1656
			16	2515	-2601	7009	-6688	1676	-1732
			17	2450	-2662	6871	-6711	1662	-1692
		SUM		42629	-44728	117162	-114562	28595	-28948
		MEAN		2507.58	-2631.61	6891.88	-6738.92	1682.05	-1702.83
	TOTAL	SUM		378590	-399141	1064213	-995813	258165	-258074
	TOTAL	MEAN		2474.44	-2608.7	6955.64	-6508.5	1687.353	-1686.7
				2588	-2788	7169	-6811	1759	-1755

Table 10: Control test begin, subjects 1-9: Velocity (units: deg/sec)

subject	velocity	item	max flex	min flex	max pro	min pro	max rad	min rad
c1	t1	1	118	-105	299	-264	69	-69
		2	122	-101	269	-262	56	-79
		3	116	-110	268	-257	58	-64
		4	114	-105	254	-243	58	-76
		5	112	-104	287	-261	79	-81
		6	99	-103	311	-259	65	-82
		7	101	-102	262	-245	54	-86
		8	102	-99	273	-276	59	-74
		9	112	-98	252	-257	66	-68
		10	110	-102	242	-290	69	-60
		11	118	-103	268	-281	68	-58
		12	115	-104	292	-267	64	-59
		13	116	-97	265	-271	72	-62
		14	114	-118	279	-261	81	-61
		15	106	-116	285	-264	67	-68
		16	105	-115	295	-269	69	-65
		17	113	-103	291	-270	78	-59
		SUM	1893	-1785	4692	-4497	1132	-1171
		MEAN	111.352	-105.22	276.55	-264.52	66.58	-68.88
c2	t1	1	119	-108	266	-276	58	-73
		2	118	-107	265	-280	61	-70
		3	116	-105	288	-279	63	-69
		4	112	-113	276	-286	66	-61
		5	111	-114	252	-291	62	-62
		6	113	-104	288	-292	67	-63
		7	112	-116	299	-299	73	-66
		8	108	-117	310	-284	71	-65
		9	107	-118	305	-278	64	-67
		10	106	-114	282	-262	63	-68
		11	102	-104	284	-266	65	-69
		12	106	-105	295	-274	67	-71
		13	104	-109	275	-281	68	-72
		14	109	-103	269	-255	61	-73
		15	104	-101	275	-266	69	-78
		16	111	-106	281	-279	62	-75
		17	109	-108	299	-271	64	-72
		SUM	1867	-1852	4809	-4719	1104	-1174
		MEAN	109.823	-108.94	282.88	-277.58	64.94	-69.05
c3	t1	1	118	-106	292	-276	62	-73
		2	104	-107	269	-288	63	-77
		3	106	-108	270	-296	71	-75
		4	103	-118	296	-278	64	-68
		5	102	-121	285	-276	65	-69
		6	104	-103	279	-297	66	-82
		7	105	-104	310	-275	59	-77

			8	113	-105	306	-261	58	-79
			9	115	-99	292	-288	69	-75
			10	117	-113	281	-262	68	-76
			11	112	-114	288	-288	67	-74
			12	107	-112	294	-276	71	-68
			13	102	-121	276	-265	76	-68
			14	103	-116	269	-267	78	-71
			15	106	-114	275	-263	79	-69
			16	109	-105	265	-277	68	-74
			17	104	-110	271	-265	72	-71
		SUM		1830	-1876	4818	-4698	1156	-1246
		MEAN		107.64	-110.35	283.411	-276.35	68.02	-73.29
c4	t1		1	106	-120	296	-269	68	-74
			2	112	-144	278	-288	61	-80
			3	106	-119	259	-265	59	-72
			4	108	-121	261	-261	58	-68
			5	107	-108	275	-287	62	-71
			6	106	-116	279	-283	64	-75
			7	105	-113	262	-287	63	-76
			8	110	-114	265	-269	71	-73
			9	111	-109	275	-265	68	-66
			10	113	-115	281	-287	67	-62
			11	114	-104	291	-261	66	-68
			12	105	-106	255	-284	61	-61
			13	110	-107	254	-277	70	-58
			14	113	-108	257	-267	69	-62
			15	108	-113	261	-288	61	-56
			16	107	-116	265	-271	62	-63
			17	118	-109	287	-277	64	-64
		SUM		1859	-1942	4601	-4686	1094	-1149
		MEAN		109.352	-114.23	270.64	-275.64	64.35	-67.58
C5	t1		1	148	-112	256	-262	68	-71
			2	122	-110	275	-281	69	-78
			3	119	-109	288	-276	71	-66
			4	143	-107	265	-279	65	-78
			5	121	-106	285	-269	68	-69
			6	114	-99	301	-275	74	-68
			7	126	-103	276	-287	69	-65
			8	116	-104	291	-286	63	-71
			9	120	-102	278	-276	65	-74
			10	117	-107	276	-279	71	-78
			11	117	-106	276	-262	70	-71
			12	120	-105	289	-279	75	-69
			13	119	-108	265	-284	81	-78
			14	112	-103	269	-299	82	-73
			15	122	-102	276	-291	77	-71
			16	118	-101	269	-287	69	-76

		17	115	-98	277	-302	68	-75
		SUM	2069	-1782	4712	-4774	1205	-1231
		MEAN	121.70	-104.82	277.17	-280.82	70.88	-72.41
c6	t1	1	118	-117	256	-281	71	-71
		2	107	-118	276	-275	69	-72
		3	104	-114	289	-288	66	-63
		4	103	-118	291	-291	72	-65
		5	110	-116	268	-288	76	-77
		6	107	-101	287	-276	71	-61
		7	106	-105	296	-265	68	-77
		8	105	-112	276	-273	67	-81
		9	99	-103	279	-299	56	-71
		10	98	-104	283	-263	51	-77
		11	112	-116	269	-296	66	-73
		12	116	-117	299	-278	73	-72
		13	119	-121	310	-266	71	-61
		14	121	-125	306	-287	66	-63
		15	124	-126	287	-306	60	-68
		16	123	-127	285	-281	56	-69
		17	119	-119	288	-283	58	-75
		SUM	1891	-1959	4845	-4796	1117	-1196
		MEAN	111.23	-115.23	285	-282.11	65.70	-70.35
c7	t1	1	118	-119	296	-276	53	-71
		2	107	-117	302	-288	56	-72
		3	121	-118	276	-275	65	-69
		4	106	-107	288	-278	61	-68
		5	115	-109	275	-264	68	-65
		6	114	-110	265	-301	69	-74
		7	108	-112	266	-298	71	-71
		8	112	-106	269	-274	75	-73
		9	107	-103	271	-265	76	-74
		10	106	-105	258	-256	78	-73
		11	116	-104	271	-258	77	-81
		12	117	-107	264	-261	71	-79
		13	124	-99	275	-279	72	-66
		14	126	-102	265	-275	68	-65
		15	121	-101	273	-269	69	-72
		16	119	-114	254	-255	67	-75
		17	107	-113	278	-263	70	-78
		SUM	1944	-1846	4646	-4635	1166	-1226
		MEAN	114.35	-108.58	273.29	-272.64	68.58	-72.11
c8	t1	1	118	-119	299	-279	76	-74
		2	117	-118	288	-275	64	-76
		3	106	-122	301	-269	69	-81
		4	105	-115	278	-279	68	-82
		5	109	-116	277	-292	71	-74

			6	110	-114	269	-256	75	-76
			7	98	-103	265	-265	69	-71
			8	97	-102	268	-268	81	-69
			9	105	-105	259	-271	71	-68
			10	106	-118	272	-281	69	-73
			11	116	-117	273	-285	65	-68
			12	117	-115	281	-269	68	-64
			13	105	-116	285	-265	59	-69
			14	104	-104	299	-264	63	-61
			15	101	-103	305	-279	62	-67
			16	106	-110	295	-267	71	-65
			17	103	-119	297	-288	79	-74
		SUM		1823	-1916	4811	-4652	1180	-1212
		MEAN		107.23	-112.70	283	-273.64	69.41	-71.29
c9	t1		1	102	-112	276	-267	69	-71
			2	101	-115	266	-255	68	-65
			3	104	-125	256	-251	65	-68
			4	106	-121	275	-262	69	-69
			5	118	-119	279	-267	66	-61
			6	117	-106	288	-268	62	-69
			7	112	-108	289	-269	68	-82
			8	115	-109	291	-271	71	-75
			9	114	-116	268	-275	72	-77
			10	113	-104	255	-279	76	-79
			11	102	-103	271	-278	79	-81
			12	105	-99	275	-281	81	-68
			13	109	-98	301	-269	73	-66
			14	119	-101	288	-267	72	-68
			15	117	-100	295	-281	74	-69
			16	122	-106	271	-274	75	-67
			17	119	-108	269	-295	73	-79
		SUM		1895	-1850	4713	-4609	1213	-1214
		MEAN		111.470	-108.82	277.23	-271.11	71.352	-71.411
	TOTAL	SUM		17071	-16808	42647	-42066	10367	-10819
	TOTAL	MEAN		111.57	-109.85	278.73	-274.94	67.75	-70.71

Table 11: Control test end, subjects 1-9: Velocity (units: deg/sec)

subject	velocity	item	max flex	min flex	max pro	min pro	max rad	min rad
c1	t2	1	119	-113	263	-277	69	-84
		2	122	-117	265	-265	71	-85
		3	125	-115	266	-288	65	-79
		4	121	-106	271	-302	76	-70
		5	116	-105	288	-285	62	-71
		6	115	-107	302	-257	67	-75
		7	114	-108	299	-279	76	-78
		8	113	-103	306	-264	74	-85
		9	110	-102	279	-299	65	-76
		10	105	-104	288	-262	75	-77
		11	106	-115	292	-274	72	-78
		12	109	-117	275	-289	69	-69
		13	113	-125	264	-274	71	-72
		14	112	-128	281	-285	76	-69
		15	104	-119	292	-291	67	-63
		16	109	-117	287	-272	71	-67
		17	107	-115	274	-288	72	-76
		SUM	1920	-1916	4792	-4751	1198	-1274
		MEANS	112.94	-112.70	281.88	-279.47	70.47	-74.94
c2	t2	1	119	-118	289	-281	65	-71
		2	118	-119	276	-287	68	-74
		3	119	-119	258	-261	79	-84
		4	117	-117	265	-278	73	-79
		5	116	-116	279	-291	76	-72
		6	105	-118	284	-269	74	-79
		7	115	-119	288	-287	77	-68
		8	114	-113	291	-265	78	-69
		9	103	-110	286	-271	82	-76
		10	112	-109	297	-285	75	-75
		11	111	-119	291	-294	74	-77
		12	110	-118	289	-273	75	-78
		13	109	-124	279	-279	76	-72
		14	108	-125	297	-287	72	-74
		15	107	-114	310	-277	73	-73
		16	106	-108	299	-299	69	-72
		17	115	-112	305	-287	71	-69
		SUM	1904	-1978	4883	-4771	1257	-1262
		MEAN	112	-116.35	287.23	-280.64	73.941	-74.23
c3	t2	1	102	-116	296	-298	67	-78
		2	113	-115	256	-279	80	-81
		3	114	-126	276	-280	79	-78
		4	105	-111	310	-269	68	-68
		5	106	-110	299	-279	67	-74
		6	114	-119	289	-268	87	-74

			7	117	-113	286	-275	68	-76
			8	118	-108	265	-270	69	-64
			9	113	-106	295	-268	76	-65
			10	112	-107	282	-297	72	-66
			11	111	-106	268	-287	80	-68
			12	110	-105	295	-274	79	-69
			13	112	-111	271	-301	77	-71
			14	113	-112	282	-275	69	-72
			15	114	-114	292	-276	68	-69
			16	114	-116	299	-286	67	-65
			17	107	-124	306	-285	62	-75
		SUM		1895	-1919	4867	-4767	1235	-1213
		MEAN		111.47	-112.88	286.29	-280.41	72.64	-71.35
c4	t2		1	112	-118	267	-255	79	-79
			2	110	-117	278	-261	61	-69
			3	107	-114	269	-266	67	-61
			4	106	-116	255	-265	77	-65
			5	114	-104	287	-255	76	-70
			6	108	-103	268	-279	66	-65
			7	119	-112	269	-310	67	-63
			8	110	-119	271	-299	78	-64
			9	113	-118	275	-287	71	-66
			10	115	-113	276	-295	73	-69
			11	107	-107	287	-291	68	-71
			12	108	-108	299	-288	61	-78
			13	109	-109	310	-265	59	-65
			14	114	-110	305	-275	72	-64
			15	108	-112	297	-281	71	-71
			16	117	-116	281	-279	65	-82
			17	103	-125	268	-276	76	-74
		SUM		1880	-1921	4762	-4727	1187	-1176
		MEAN		110.58	-113	280.117	-278.05	69.823	-69.176
c5	t2		1	127	-112	276	-278	64	-75
			2	122	-118	265	-277	69	-69
			3	106	-117	259	-275	68	-68
			4	119	-106	257	-295	83	-78
			5	105	-105	244	-275	78	-75
			6	104	-119	288	-279	69	-73
			7	115	-125	289	-276	68	-75
			8	116	-116	295	-277	67	-74
			9	119	-118	287	-261	69	-73
			10	117	-107	278	-263	72	-74
			11	125	-103	268	-275	73	-78
			12	124	-115	295	-269	77	-69
			13	107	-106	276	-286	69	-77
			14	104	-109	269	-255	81	-75
			15	112	-110	274	-267	76	-71

			16	119	-116	279	-277	71	-69
			17	114	-108	307	-271	75	-78
		SUM		1955	-1910	4706	-4656	1229	-1251
		MEAN		115	-112.35	276.82	-273.88	72.29	-73.58
c6	t2		1	101	-112	289	-269	75	-74
			2	109	-116	287	-267	69	-75
			3	112	-119	295	-306	77	-78
			4	126	-118	317	-285	68	-77
			5	107	-121	298	-274	67	-81
			6	115	-118	322	-264	71	-76
			7	114	-116	291	-256	72	-75
			8	120	-115	295	-274	68	-64
			9	113	-117	296	-273	67	-69
			10	118	-119	274	-268	66	-63
			11	119	-110	284	-264	79	-70
			12	117	-112	285	-259	71	-72
			13	116	-116	286	-261	81	-73
			14	115	-117	281	-274	79	-77
			15	115	-118	276	-273	83	-74
			16	114	-122	269	-268	64	-71
			17	123	-119	316	-266	69	-69
		SUM		1954	-1985	4961	-4601	1226	-1238
		MEAN		114.94	-116.76	291.82	-270.64	72.117	-72.82
c7	t2		1	101	-101	276	-277	67	-77
			2	103	-105	286	-269	65	-71
			3	98	-110	298	-264	68	-78
			4	107	-112	269	-287	69	-81
			5	115	-113	294	-292	71	-71
			6	113	-114	271	-291	75	-79
			7	121	-115	262	-278	72	-77
			8	125	-110	264	-277	78	-76
			9	118	-108	299	-265	79	-75
			10	116	-109	301	-269	81	-77
			11	106	-112	312	-268	70	-69
			12	104	-107	287	-271	69	-67
			13	107	-106	273	-285	65	-76
			14	106	-105	285	-289	61	-81
			15	105	-116	284	-295	65	-80
			16	103	-105	278	-273	68	-74
			17	102	-106	271	-281	69	-73
		SUM		1850	-1854	4810	-4731	1192	-1282
		MEAN		108.82	-109.05	282.94	-278.29	70.117	-75.41
c8	t2		1	117	-119	276	-268	78	-76
			2	116	-118	286	-271	77	-73
			3	119	-107	275	-256	76	-70
			4	121	-116	279	-309	66	-72

			5	125	-119	281	-286	69	-65
			6	108	-121	308	-274	71	-71
			7	106	-113	299	-268	75	-68
			8	108	-116	302	-269	74	-74
			9	107	-117	286	-255	76	-72
			10	111	-105	287	-254	72	-71
			11	113	-108	284	-275	71	-70
			12	106	-117	289	-277	69	-75
			13	109	-126	296	-268	98	-71
			14	110	-108	299	-279	73	-75
			15	116	-110	294	-271	72	-76
			16	115	-117	296	-285	75	-81
			17	107	-116	288	-284	74	-83
		SUM		1914	-1953	4925	-4649	1266	-1243
		MEAN		112.58	-114.88	289.70	-273.47	74.47	-73.11
c9	t1		1	108	-119	307	-286	71	-77
			2	107	-118	316	-285	78	-71
			3	119	-107	298	-279	75	-73
			4	116	-118	269	-275	74	-74
			5	118	-118	285	-281	73	-75
			6	117	-107	279	-286	75	-71
			7	125	-109	286	-283	76	-72
			8	121	-110	265	-269	79	-69
			9	126	-119	298	-264	74	-76
			10	118	-115	288	-284	72	-65
			11	119	-121	278	-264	75	-78
			12	118	-125	295	-253	77	-67
			13	117	-118	296	-279	79	-73
			14	116	-112	282	-275	76	-71
			15	109	-107	287	-281	71	-73
			16	110	-110	286	-279	72	-75
			17	112	-116	284	-275	73	-78
		SUM		1976	-1949	4899	-4698	1270	-1238
		MEAN		116.23	-114.64	288.176	-276.35	74.705	-72.82
	TOTAL	SUM		17248	-17385	43605	-42351	11060	-11177
	TOTAL	MEAN		112.73	-113.62	285	-276.80	72.28	-73.05

Table 12: Control test begin, subjects 1-9: Position (units: degrees)

subject	position	item	max flex	min flex	max pro	min pro	max rad	min rad
c1	t1	1	7.25	-27.05	38.61	-36.63	5.2	-16.92
		2	6.11	-26.28	39.65	-37.25	4.68	-17.89
		3	6.1	-26.18	41.02	-33.46	3.22	-17.65
		4	5.99	-23.57	45.36	-37.97	3.11	-18.01
		5	6.12	-25.49	45.49	-38.91	3.26	-17.96
		6	4.46	-25.61	45.68	-40.23	2.25	-18.32
		7	4.86	-25.34	46.21	-37.65	1.18	-17.86
		8	4.89	-28.78	38.71	-37.22	2.25	-17.89
		9	5.1	-25.61	38.91	-35.64	2.86	-17.61
		10	5.11	-24.79	38.62	-34.33	3.98	-17.05
		11	5.32	-24.29	38.34	-32.78	2.92	-18.46
		12	5.31	-23.46	38.51	-31.16	1.64	-18.32
		13	5.46	-26.54	41.23	-35.61	1.88	-18.69
		14	4.77	-27.61	42.68	-35.28	2.77	-18.11
		15	4.76	-28.85	43.67	-39.61	2.91	-18.25
		16	6.12	-29.82	43.92	-34.66	3.93	-18.06
		17	6.13	-29.01	43.78	-34.58	4.04	-18.89
		SUM	93.86	-448.28	710.39	-612.97	52.08	-305.94
		MEAN	5.52	-26.36	41.787	-36.05	3.06	-17.99
c2	t1	1	4.38	-27.08	37.61	-38.67	4.78	-16.54
		2	4.41	-26.22	38.96	-34.65	3.51	-18.09
		3	4.61	-25.87	35.51	-39.22	5.25	-17.79
		4	4.71	-25.64	36.91	-41.56	2.36	-17.14
		5	4.77	-23.79	37.81	-40.23	3.22	-17.92
		6	4.44	-23.88	39.63	-41.23	3.87	-17.96
		7	5.32	-23.91	35.22	-38.66	3.73	-16.54
		8	5.68	-24.61	37.79	-35.64	4.91	-16.92
		9	6.11	-28.28	38.11	-37.36	3.94	-16.84
		10	6.32	-26.93	39.22	-38.61	2.93	-17.84
		11	4.91	-27.11	40.23	-37.98	2.95	-17.08
		12	4.36	-27.45	46.88	-35.22	2.88	-18.64
		13	4.88	-27.81	47.79	-38.11	1.97	-18.89
		14	4.75	-26.63	47.22	-34.65	1.88	-18.91
		15	6.22	-27.85	47.36	-33.22	2.87	-18.08
		16	6.39	-24.46	46.12	-37.84	2.82	-18.11
		17	4.87	-29.63	39.61	-34.62	1.82	-17.42
		SUM	87.13	-447.15	691.98	-637.47	55.69	-300.71
		MEAN	5.12	-26.30	40.70	-37.49	3.27	-17.68
c3	t1	1	4.88	-26.99	40.25	-33.26	2.13	-18.19
		2	5.39	-27.75	38.99	-31.64	2.16	-18.12
		3	5.61	-29.01	37.81	-34.68	3.34	-18.01
		4	3.99	-28.86	40.25	-38.91	1.12	-18.22
		5	4.61	-28.61	39.61	-35.61	2.79	-16.91
		6	4.68	-27.49	47.03	-39.74	1.85	-17.06
		7	4.73	-28.15	49.62	-34.62	1.86	-16.81

			8	5.42	-27.91	40.02	-32.22	2.25	-16.79
			9	5.68	-26.87	39.22	-34.61	3.05	-16.32
			10	5.75	-26.51	39.68	-35.98	3.14	-16.55
			11	4.96	-29.64	42.25	-31.12	2.99	-16.84
			12	4.51	-23.97	43.65	-40.16	1.97	-17.46
			13	6.32	-25.29	46.89	-38.97	1.76	-18.51
			14	6.21	-25.56	45.32	-32.55	2.78	-17.22
			15	4.67	-24.49	45.21	-37.89	1.88	-17.69
			16	5.05	-24.41	40.09	-39.22	2.85	-17.56
			17	5.08	-24.67	41.51	-41.01	1.83	-17.88
		SUM		87.54	-456.18	717.4	-612.19	39.75	-296.14
		MEAN		5.14	-26.83	42.2	-36.01	2.33	-17.42
c4	t1		1	6.11	-28.07	44.79	-31.22	3.69	-16.83
			2	6.09	-24.44	43.38	-38.65	2.84	-18.84
			3	4.96	-29.07	42.26	-34.56	3.95	-16.72
			4	5.18	-26.97	41.25	-33.22	2.92	-17.84
			5	5.78	-27.65	38.97	-31.11	1.86	-17.68
			6	5.69	-27.47	47.06	-29.7	2.88	-17.44
			7	5.31	-28.54	41.23	-35.61	3.92	-16.23
			8	4.97	-29.03	39.66	-34.62	3.96	-16.61
			9	4.85	-29.31	39.87	-33.54	4.89	-17.52
			10	6.21	-25.33	39.65	-38.71	2.83	-16.98
			11	6.46	-24.44	39.65	-32.54	2.44	-18.45
			12	5.31	-26.91	40.23	-32.61	1.32	-18.32
			13	6.28	-28.17	45.61	-34.91	1.17	-18.22
			14	4.68	-26.65	47.25	-34.66	1.07	-17.64
			15	5.25	-27.64	47.87	-38.71	2.25	-17.96
			16	5.27	-28.63	43.65	-37.46	2.77	-17.63
			17	5.81	-29.02	410.2	-33.21	3.88	-17.55
		SUM		94.21	-467.34	1092.58	-585.04	48.64	-298.46
		MEAN		5.54	-27.49	64.26	-34.41	2.861	-17.55
c5	t1		1	6.09	-25.61	44.66	-32.25	3.11	-18.22
			2	5.88	-24.75	43.22	-34.61	2.05	-16.97
			3	4.68	-23.91	40.23	-34.22	2.94	-16.58
			4	5.67	-23.54	38.77	-38.11	3.98	-16.44
			5	5.35	-28.11	43.23	-36.21	4.12	-16.32
			6	5.21	-29.87	48.76	-35.32	3.07	-16.92
			7	4.79	-24.61	45.91	-34.71	4.89	-16.45
			8	4.64	-26.05	44.21	-37.85	3.84	-17.56
			9	5.64	-27.75	44.69	-37.66	1.17	-18.61
			10	5.34	-24.98	43.35	-37.22	1.03	-19.01
			11	5.28	-24.32	42.65	-34.61	2.16	-18.88
			12	5.17	-24.61	41.78	-37.28	2.79	-18.56
			13	5.97	-23.58	41.65	-36.22	4.83	-18.02
			14	5.61	-22.11	41.23	-38.21	1.87	18.14
			15	5.36	-25.33	39.22	-34.55	1.06	-18.22
			16	5.45	-27.34	38.76	-34.28	2.99	-17.86

		17	5.15	-27.33	39.91	-32.38	1.93	-16.88
		SUM	91.28	-433.8	722.23	-605.69	47.83	-263.36
		MEAN	5.36	-25.51	42.48	-35.62	2.81	-15.49
c6	t1	1	5.68	-24.41	38.79	-38.61	3.79	-16.97
		2	5.27	-23.38	45.61	-37.55	2.82	-16.32
		3	5.32	-25.54	44.69	-38.51	3.86	-16.87
		4	5.44	-27.91	44.67	-32.61	1.32	-17.62
		5	5.36	-24.64	43.68	-31.85	1.97	-17.95
		6	5.55	-28.66	41.69	-32.22	1.81	-17.46
		7	5.25	-23.54	41.05	-33.41	1.22	-18.51
		8	5.74	-23.87	42.26	-36.61	2.25	-16.22
		9	5.33	-24.34	39.25	-37.51	2.23	-16.95
		10	6.54	-25.63	44.78	-34.65	4.01	-17.85
		11	6.18	-26.16	44.98	-35.62	3.33	-17.63
		12	6.8	-26.77	44.35	-33.22	4.54	-18.25
		13	6.22	-28.89	45.21	-34.91	4.33	-16.98
		14	4.32	-27.54	45.63	-31.65	3.06	-17.74
		15	5.43	-27.17	42.23	-38.51	3.25	-17.56
		16	4.44	-29.33	38.56	-32.24	2.25	-18.51
		17	6.36	-29.26	38.71	-32.87	2.89	-18.08
		SUM	95.23	-447.04	726.14	-592.55	48.93	-297.47
		MEAN	5.60	-26.29	42.71	-34.85	2.87	-17.49
c7	t1	1	4.71	-28.06	39.62	-36.66	1.78	-17.92
		2	6.22	-25.67	45.61	-37.51	1.86	-17.89
		3	4.41	-25.31	48.77	-34.21	2.85	-18.06
		4	4.48	-24.49	45.98	-33.34	3.12	-17.28
		5	5.05	-28.44	44.61	-33.91	3.84	-17.25
		6	5.18	-28.97	43.74	-33.47	3.87	-17.33
		7	5.51	-25.67	43.36	-38.56	2.91	-16.52
		8	6.12	-25.64	42.25	-36.22	2.83	-18.91
		9	6.32	-25.91	39.62	-37.84	2.96	-17.61
		10	4.98	-25.87	38.46	-35.21	1.92	-17.05
		11	5.38	-24.63	38.76	-32.27	1.32	-16.92
		12	5.36	-24.22	39.62	-32.98	1.56	-16.91
		13	4.44	-24.31	38.16	-34.61	2.11	-17.05
		14	4.26	-25.61	47.36	-33.51	2.36	-18.33
		15	5.21	-29.02	41.3	-34.97	2.46	-18.65
		16	5.48	-29.23	45.22	34.29	2.87	-18.22
		17	4.66	-28.01	35.62	-37.61	3.04	-18.01
		SUM	87.77	-449.06	718.06	-528.59	43.66	-299.91
		MEAN	5.162	-26.41	42.23	-31.09	2.56	-17.64
c8	t1	1	4.57	-29.01	47.61	-29.62	1.89	-17.85
		2	4.52	-24.61	42.23	-37.51	2.84	-17.77
		3	4.41	-28.51	39.99	-34.66	3.22	-17.69
		4	4.34	-28.92	38.78	-37.58	3.93	-17.56
		5	4.39	-28.81	40.78	-37.51	3.64	-18.31

			6	4.54	-25.78	42.56	-35.21	3.76	-18.91
			7	4.61	-24.16	41.23	-30.06	3.78	-18.43
			8	4.81	-26.66	39.65	-32.17	1.87	-18.32
			9	4.92	-23.98	39.61	-31.68	1.65	-18.54
			10	4.61	-24.66	38.92	-39.87	1.33	-18.61
			11	5.23	-28.91	38.77	-38.56	1.25	-16.98
			12	5.26	-27.22	39.61	-37.24	2.25	-17.46
			13	5.78	-26.13	40.11	-38.91	2.27	-17.55
			14	6.01	-2.22	41.36	-38.95	3.39	-18.23
			15	5.56	-27.71	40.02	-36.91	3.83	-18.96
			16	4.94	-25.01	39.62	-36.27	4.06	-18.65
			17	6.11	-24.48	38.77	-30.07	2.98	-18.77
		SUM		84.61	-426.78	689.62	-602.78	47.94	-308.59
		MEAN		4.977	-25.10	40.56	-35.45	2.82	-18.15
c9	t1		1	6.02	-25.36	46.61	-37.61	3.07	-18.22
			2	5.99	-27.11	40.09	-37.52	3.55	-17.54
			3	6.11	-27.27	43.21	-36.91	2.61	-16.98
			4	5.87	-26.62	45.22	-38.99	1.32	-18.33
			5	5.76	-25.36	37.99	-41.05	2.64	-17.22
			6	5.64	-26.01	38.65	-35.64	2.87	-17.01
			7	5.32	-25.62	41.25	-32.18	3.61	-16.78
			8	5.98	-25.69	40.02	-34.91	3.59	-16.98
			9	5.12	-25.89	39.61	-36.92	1.16	-17.56
			10	4.87	-25.75	37.52	-35.61	1.68	-18.15
			11	4.65	-26.11	38.65	-37.88	2.89	-18.43
			12	5.03	-25.55	39.68	-39.61	2.87	-18.54
			13	5.99	-23.81	42.25	-33.25	2.55	-16.92
			14	4.87	-23.79	44.32	-34.61	4.01	-16.91
			15	4.99	-23.51	47.16	-34.98	3.98	-16.87
			16	5.26	-23.7	35.26	-30.05	3.77	-16.32
			17	6.11	-23.66	38.69	-34.75	3.86	-16.22
		SUM		93.58	-430.81	696.18	-612.47	50.03	-294.98
		MEAN		5.504	-25.34	40.95	-36.02	2.94	-17.35
	TOTAL	SUM		815.21	-4006.42	6764.58	-5389.71	434.55	-2665.50
	TOTAL	MEAN		90.57	-445.16	751.62	-598.86	48.28	-296.17

Table 13: Control test end, subjects 1-9: Position (unit: degrees)

subject	position	item	max flex	min flex	max pro	min pro	max rad	min rad
c1	t2							
		1	4.21	-20.05	36.61	-29.88	1.01	-14.22
		2	4.15	-21.97	36.22	-31.22	1.02	-14.65
		3	4.22	-22.35	36.51	-30.29	1.03	-14.78
		4	2.98	-23.61	35.23	-29.65	1.05	-15.01
		5	3.22	-21.87	35.26	-28.77	1.16	-15.22
		6	4.11	-21.55	35.29	-30.22	1.1	-15.36
		7	4.25	-21.06	35.98	-30.25	1.05	-15.69
		8	4.44	-19.77	35.87	-30.65	1.06	-15.23
		9	4.34	-20.16	36.64	-29.56	0.98	-15.96
		10	3.99	-21.34	37.01	-29.17	1.02	-16.01
		11	4.18	-21.08	37.22	-29.61	1.06	-16.22
		12	4.27	-20.06	35.62	-29.62	1.03	-16.22
		13	4.25	-20.88	35.11	-28.32	1.04	-16.38
		14	4.29	-21.75	34.22	-28.64	1.05	-15.69
		15	4.33	-22.39	34.19	-28.22	1.11	-15.67
		16	4.18	-21.08	34.28	-28.67	1.12	-15.06
		17	4.56	-21.99	34.25	-28.33	1.15	-15.22
		SUM	69.97	-362.96	605.51	-501.07	18.04	-262.59
		MEAN	4.115	-21.350	35.618	-29.474	1.061	-15.446
c2	t2							
		1	4.08	-20.88	33.71	-29.63	1.11	-16.22
		2	4.04	-21.36	35.62	-30.25	1.15	-16.02
		3	3.91	-19.99	35.34	-30.65	1.06	-16.55
		4	4.07	-20.16	35.62	-31.25	1.05	-16.75
		5	3.65	-21.34	35.91	-31.69	1.04	-16.21
		6	4.01	-21.77	35.26	-31.58	1.11	-15.96
		7	4.02	-19.65	35.91	-31.54	1.02	-14.79
		8	4.13	-21.66	35.26	-31.58	1.06	-14.68
		9	4.19	-20.17	35.87	-31.59	1.08	-15.32
		10	4.22	-20.88	35.21	-31.58	1.04	-15.68
		11	4.25	-18.96	35.69	-31.68	1.06	-15.87
		12	4.44	-19.33	35.18	-31.25	1.05	-15.69
		13	4.28	-21.87	35.22	-31.68	1.02	-15.32
		14	4.27	-20.68	35.35	-31.28	1.13	-16.02
		15	4.32	-20.67	35.11	-35.22	1.12	-16.33
		16	4.28	-21.66	34.21	-31.58	1.07	-16.68
		17	4.26	-22.91	34.13	-31.58	1.09	-16.28
		SUM	70.42	-353.94	598.62	-535.61	18.26	-270.37
		MEAN	4.14	-20.82	35.21	-31.50	1.074	-15.90
c3	t2	1	4.07	-21.87	34.33	-29.68	1.1	-15.19
		2	4.12	-22.35	34.62	-29.64	1.01	-15.22
		3	3.98	-22.65	35.29	-29.31	1.12	-15.61
		4	4.11	-23.68	35.85	-28.65	1.13	-15.32
		5	4.23	-23.66	34.61	-31.25	1.04	-15.77

			6	4.02	-22.54	35.96	-31.05	1.02	-15.69
			7	3.88	-23.91	36.56	-31.06	1.03	-15.32
			8	3.79	-21.18	36.87	-31.08	1.02	-15.27
			9	3.67	-21.16	35.29	-31.08	1.05	-15.87
			10	3.98	-22.36	30.25	-29.65	1.06	-15.36
			11	4.15	-21.39	35.62	-29.65	1.04	-16.01
			12	4.19	-22.91	30.24	-29.38	1.02	-16.32
			13	3.98	-21.68	35.98	-29.31	1.18	-16.15
			14	4.11	-21.69	37.62	-30.25	1.16	-16.98
			15	4.07	-22.15	35.62	-31.65	1.12	-16.57
			16	4.15	-21.78	37.02	-32.25	1.13	-16.02
			17	4.22	-22.61	37.33	32.07	1.01	-16.33
		SUM		68.72	-379.57	599.06	-452.87	18.24	-269
		MEAN		4.04	-22.32	35.23	-26.63	1.07	-15.82
c4	t2		1	4.04	-19.88	37.69	-30.77	1.11	-14.46
			2	4.06	-21.87	37.06	-30.55	1.1	-14.99
			3	4.18	-20.66	35.91	-29.66	1	-14.87
			4	3.99	-20.31	35.88	-29.87	1.02	-14.65
			5	4.11	-22.68	35.62	-32.21	1.05	-15.32
			6	4.06	-21.69	35.94	-30.94	1.05	-15.69
			7	4.03	-24.55	35.62	-30.26	1.08	-15.28
			8	4.12	-23.95	35.87	-32.87	1.07	-15.97
			9	4.05	-20.77	36.25	-30.25	1.06	-15.39
			10	4.01	-19.98	36.58	-30.26	1.03	-15.27
			11	3.97	-23.11	36.15	-30.25	1.02	-15.68
			12	3.98	-23.14	36.07	-30.26	1.05	-15.32
			13	3.87	-22.58	36.09	-31.25	1.06	-15.99
			14	4.16	-21.77	35.62	-32.25	1.04	-15.27
			15	4.14	-24.68	35.28	-32.65	1.05	-15.69
			16	4.22	-20.18	35.91	-32.87	1.02	-16.21
			17	4.17	-22.64	35.62	-32.14	1.01	-15.99
		SUM		69.16	-374.4	613.16	-529.31	17.82	-262.04
		MEAN		4.06	-22.02	36.06	-31.13	1.04	-15.41
c5	t2			4.35	-23.58	37.36	-30.25	1.12	-16.51
			1	3.77	-22.07	32.26	-30.25	1.12	-14.88
			2	3.98	-23.11	33.65	-30.26	1.15	-14.69
			3	4.07	-23.65	34.56	-31.25	1.02	-15.32
			4	4.22	-23.18	38.11	-32.25	1.03	-15.68
			5	4.11	-23.22	34.56	-32.29	1.05	-15.97
			6	4.18	-22.51	35.61	-32.65	1.06	-15.32
			7	4.07	-22.67	35.69	-32.25	1.02	-15.69
			8	4.24	-22.95	36.11	-31.25	1.04	-15.28
			9	4.23	-21.85	36.25	-32.25	1.05	-15.32
			10	4.21	-21.65	36.91	-31.68	1.11	-16.01
			11	4.08	-22.38	36.54	-31.65	1.12	-16.25
			12	4.09	-21.78	36.28	-31.29	1.11	-16.32
			13	4.11	-22.87	36.51	-32.25	1.06	-15.32

		14	3.99	-22.33	36.28	-31.06	1.08	-16.12
		15	4.03	-22.47	30.25	-31.58	1.05	-16.33
		16	4.02	-22.88	33.24	-32.25	1.02	-15.97
		17	3.97	-23.54	31.88	-31.69	1.04	-15.75
		SUM	69.37	-385.11	594.6	-538.15	18.13	-266.22
		MEAN	4.08	-22.65	34.98	-31.65	1.066	-15.66
c6	t2	1	4.02	-21.77	35.65	-30.25	1.05	-14.88
		2	4.03	-22.08	35.21	-30.24	1.03	-15.55
		3	4.11	-23.44	35.29	-30.26	1.02	-15.62
		4	4.13	-22.61	35.98	-31.25	1.11	-15.38
		5	4.26	-23.54	36.01	-31.68	1.13	-15.21
		6	4.32	-23.69	36.25	-31.67	1.04	-15.69
		7	4.28	-23.87	34.87	-31.59	1.05	-15.32
		8	4.38	-23.61	34.89	-31.68	1.06	-15.21
		9	4.06	-22.45	35.62	-31.25	1.03	-15.24
		10	4.17	-22.61	35.26	-30.25	1.07	-15.78
		11	4.13	-23.09	36.95	-29.64	1.08	-15.98
		12	4.18	-22.14	36.87	-29.65	1.09	-16.11
		13	4.15	-22.35	35.21	-32.24	1.08	-15.87
		14	4.17	-21.08	35.36	-32.11	1.05	-15.64
		15	4.12	-22.39	36.01	-32.64	1.07	-15.32
		16	4.18	-23.55	36.29	-30.21	1.06	-15.24
		17	4.21	-23.75	36.25	-31.02	1.01	-15.17
		SUM	70.9	-388.02	607.97	-527.63	18.03	-263.21
		MEAN	4.17	-22.82	35.76	-31.03	1.06	-15.48
c7	t2	1	4.25	-20.56	34.26	-29.5	1.12	-15.02
		2	4.29	-22.36	35.26	-29.65	1.13	-16.32
		3	4.23	-20.76	35.91	-31.25	1.1	-15.98
		4	4.26	-25.36	32.25	-31.24	1.05	-15.23
		5	4.21	-21.75	32.26	-31.69	1.06	-15.75
		6	4.19	-22.63	32.16	-32.58	1.05	-15.69
		7	4.15	-20.87	32.58	-32.87	1.02	-15.87
		8	4.08	-21.63	34.26	-32.54	1.03	-15.69
		9	4.19	-22.06	35.98	-31.25	1.06	-15.38
		10	4.27	-23.38	35.12	-31.69	1.05	-16.07
		11	4.06	-22.15	35.61	-31.27	1.04	-16.14
		12	4.05	-21.68	36.91	-30.26	1.05	-16.35
		13	4.03	-21.77	36.25	-30.56	1.06	-16.27
		14	4.06	-22.5	36.28	-31.24	1.09	-15.98
		15	3.99	-22.61	36.97	-30.69	1.08	-15.87
		16	4.02	-22.33	36.15	-30.99	1.05	-15.67
		17	4.05	-22.87	36.23	-33.57	1.02	-15.55
		SUM	70.38	-377.27	594.44	-532.84	18.06	-268.83
		MEAN	4.14	-22.192	34.967	-31.343	1.062	-15.813

C8	T2	1	4.11	-21.54	36.71	-28.65	1.07	-14.85
		2	4.15	-20.62	36.91	-29.61	1.06	-14.96
		3	4.26	-20.33	36.35	-31.33	1.07	-15.06
		4	4.32	-21.69	35.22	-31.25	1.05	-15.32
		5	4.28	-21.36	35.61	-31.56	1.08	-15.87
		6	4.29	-22.68	35.68	-31.05	1.06	-15.69
		7	4.31	-23.91	35.69	-32.65	1.05	-15.32
		8	4.14	-23.51	35.17	-38.56	1.06	-16.02
		9	4.13	-22.64	35.29	-31.57	1.09	-16.09
		10	4.25	-22.38	35.91	-31.28	1.04	-15.87
		11	4.17	-20.17	37.61	-30.76	1.04	-15.69
		12	4.22	-18.95	38.22	-32.65	1.05	-15.32
		13	4.18	-23.65	35.69	-34.68	1.06	-16.22
		14	4.26	-22.64	35.21	-33.25	1.02	-16.87
		15	4.31	-21.35	35.62	-32.67	1.03	-16.23
		16	4.07	-23.58	35.24	-31.65	1.05	-16.41
		17	4.09	-22.76	35.29	-34.21	1.08	-15.98
		SUM	71.54	-373.76	611.42	-547.38	17.96	-267.77
		MEAN	4.20	-21.98	35.96	-32.198	1.05	-15.75
c9	T1	1	3.99	-22.58	36.78	-30.84	1.03	-16.22
		2	4.11	-23.15	36.29	-32.65	1.02	-16.33
		3	4.15	-23.57	36.52	-31.26	1.05	-15.99
		4	4.16	-23.14	36.85	-32.68	1.06	-15.88
		5	4.31	-23.16	36.74	-31.64	1.05	-15.76
		6	4.12	-23.22	35.62	-35.21	1.04	-15.32
		7	4.05	-20.47	36.57	-31.22	1.05	-15.34
		8	4.06	-21.56	35.21	-32.24	1.06	-14.89
		9	4.07	-21.57	34.65	-33.65	1.09	-15.98
		10	4.09	-21.88	34.98	-33.69	1.08	-16.07
		11	4.12	-20.09	35.56	-33.78	1.07	-16.11
		12	4.18	-22.65	35.21	-33.68	1.04	-16.25
		13	4.23	-22.31	34.98	-34.21	1.01	-16.23
		14	4.19	-22.57	35.67	-34.97	1.05	-16.18
		15	4.14	-22.64	36.87	-34.11	1.07	-15.97
		16	4.2	-21.65	35.21	-32.69	1.04	-16.05
		17	4.18	-22.31	34.78	-31.22	1.09	-16.27
		SUM	70.35	-378.52	608.49	-559.74	17.9	-270.84
		MEAN	4.138	-22.26	35.79	-32.92	1.05	-15.931
	TOTAL	SUM	630.81	-3373.5	5433.34	-4724.62	162.44	-2400.80
	TOTAL	MEAN	4.12	-22.04	35.51	-30.87	1.061	-15.69
		BENCH	4.35	-23.58	37.36	-31.84	1.12	-16.51

APPENDIX B: MARRAS AND SCHOENMARKLIN BENCH MARK VALUES

Deg/Sec Veloc.	Rad/Ulnar Mean	Min	Max	Flex/Ext Mean	Min	Max	Pro/Sup Mean	Min	Max
H.R.mean	25.9	-115.1	115.7	42.2	-183.7	174.2	91.3	-403.2	449.2
L.R. mean	6.7	36.5	39.5	11.7	76.8	58.4	23.3	149.1	256.2
H.R. std.	17	-79.3	77.3	28.7	-121.2	120.3	67.7	-289.9	300.2
L.R. std.	6.7	34.9	31.1	7.6	42.8	38.1	19.5	112	129

Accel.	Mean	Min	Max	Mean	-4927	Max	Mean	Min	Max
H.R.mean	494	-2776	3077	824	1913	4471	1824	-11987	11291
L.R.mean	142	913	1313	268	-2788	1527	533	6330	4954
H.R. std.	301	-1755	1759	494	862	2588	1222	-6811	7169
L.R. std.	125	818	834	156		802	384	2571	2980

Position	Mean	Min	Max	Mean	-29.08	Max	Mean	Min	Max
H.R. mean	-6.73	-18.96	4.69	-12.02	7.32	6.56	8.3	-38.93	47.7
L.R.mean	4.66	5.78	4.76	7.16	-23.58	11.11	20.5	23.4	19.48
H.R. std.	-7.62	-16.51	1.12	-10.09	13.12	4.35	2.47	-31.84	37.36
L.R. std.	4.42	5.57	6.17	11.88		12.36	38.63	38.76	38.69

APPENDIX C: SAMPLE SAS PROGRAM

```
OPTIONS LINESIZE = 76;
DATA A;
INPUT    C1A1  C1A2;
CARDS;
 7202        7095
 6680        6425
 7108        6850
 6848        6717
 6802        6800
 6883        6940
 7032        6913
 7151        6758
 6891        6196
 6660        5932
 5630        6276
 6365        6242
 6582        6135
 6653        6218
 6507        6566
 6724        6598
 6713        6438
 6738        6701

proc print;
run;
data A; set A;
difference = C1A2 -C1A1;
run;
proc print;
run;
proc means data =A   mean std stderr clm t prt alpha = 0.05;
var difference;
proc print;
run;
proc univariate plot;
var C1A1 C1A2;
RUN;
```