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THE ACCURACY OF THE PERCEPTION OF SPINAL POSTURE DURING DYNAMIC LIFTING

by

Liris Patricia Reed Smith ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of *Masters of Science*

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The undersigned certify that they have read, and recommend to the faculty of Graduate Studies and Research for acceptance, a thesis entitled *The Accuracy of the Perception of Spinal Posture During Dynamic Lifting* submitted by *Liris Patricia Reed Smith* in partial fulfillment of the requirements for the degree of *Master's of Science*

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Dedication

This thesis is dedicated to my parents, Jo and Wayne Reed, for the guidance and acceptance in all things I do; and for instilling a belief in myself and a belief that all things are possible.

And, to my husband, Luke, and my two children, MacKenzie and Chandler, for their love, patience and continued support.

ABSTRACT

Forty-eight female long term care workers with a mean age of 36.65 years were asked to estimate spinal postures at the beginning, middle and end point of a dynamic lifting task. Sagittal plane postures were recorded on videotape and compared to estimated, self-drawn, line drawing postures. Using a paired t-test, significant differences, were found between the estimated and the actual postures, in all three positions. The absolute error in estimated postures ranged from 0 to 54 degrees. Data were collected on back pain, physical activity level, age and number of years of work. To determine if a relationship existed between accuracy of estimation and the independent variables, Pearson's correlation coefficients were calculated. Of the twelve correlation coefficients calculated, only two correlations reached significance.

Acknowledgements

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Chapter One

THE PROBLEM

Introduction:

Postural perception or position sense is described as the ability to evaluate subjectively. the position of a limb in space (Grigg et al, 1973). Many studies have looked at the accuracy of position sense in the peripheral joints (Wells et al, 1994; Hall et al, 1995; Robbins et al, 1995; Garn and Newton, 1988). There is little literature about spinal postural perception.

Health care occupations show high levels of postural stress (Baty & Stubbs, 1987; Buckle, 1987). In these professions people are assuming many different spinal postures and a high risk of injury is often reported (Baty & Stubbs, 1987). Though several studies have been carried out with the nursing profession, no study has dealt with postural perception during dynamic movement with this group of workers.

Posture and body mechanics are often taught as a method of injury prevention. Also, posture is often measured in a working environment to estimate the amount of stress and load on the human body(Corlett et al, 1979; Kumar, 1990; Nordin et al, 1984). Assessing posture in a quick and easy manner such as self-drawing of work postures could prove to be an convenient measurement. This study is more observational in nature. However, if subjects are able to estimate and draw working postures, this would have value and importance in the context of work assessment and subsequently, injury prevention.

The perception of spinal postures has been studied by a few researchers (Kumar, 1993a; Kumar, 1993b; Parkhurst & Burnett, 1994). However, the testing of position sense was done in a static posture. Work activities and the activities of daily living are dynamic in nature. The perception of posture and the ability of individuals to perceive spinal posture during functional and dynamic movements is yet to be studied. The purpose of this study was to assess spinal postural perception during dynamic movement with a population of health-care workers and, as a result, determine the validity of the line-drawing tool in this population. The relationship of back pain, age, and physical activity levels to accuracy, was also investigated.

Objectives:

The primary objective of this study was to determine how accurately female certified nursing assistants, nursing home attendants, rehabilitation aides and recreation attendants can estimate spinal postures, at three specific moments, in a dynamic lift, using line-drawings, compared to the actual posture, that is recorded photometrically. The validity of the line drawing tool was subsequently examined.

The second objective was to determine if the accuracy of spinal posture perception during dynamic lifting was related to age, physical activity level and back pain.

Hypotheses:

The following four hypotheses will be tested:

1. There is no significant difference between the postural angles estimated by self-drawn, line drawings and those measured through videotaped postures, for three positions of a dynamic lifting activity. Therefore, the self-drawn line drawing tool is valid with this population.
2. There is a positive correlation between increased physical activity and increased accuracy of postural perception. For this study, physical activity is defined as

activity, outside of occupation, that illicits a training effect (ie. increased heart rate, increased muscular strength or endurance, increased flexibility).

3. There is a positive correlation between increased back pain and decreased accuracy of postural perception. For this study, back pain was measured as severity of current pain, using a Visual Analog Scale (VAS).
4. There is a positive correlation between increased age and decreased accuracy of postural perception.

Limitations:

One limitation of this study is that the results that are obtained are generalizable only to female institutional aides working in long term care centers. As the health care system remains relatively uniform across Canada, and the majority of institutional aides are female. The generalizability of the study may prove to be adequate.

This study is designed to investigate postural perception during lifting. Investigating dynamic movement closely represents the actual movements of work. The limitation of this study is that only one defined movement in a single plane is being investigated. Most movements of work and daily living involve combinations of movement using all three planes of spinal motion. However, using a single movement to describe the posture and investigate the use of the line drawing tool, is an appropriate beginning. Further study in this area may be warranted for combined movements.

The effects of velocity on posture perception will not be analyzed in this study. Especially with a loaded spine, these factors may be relevant. A further study may be warranted in this area to deal with these factors.

Due to the geographic area and low population. the population size in this group of professions was only 74 people. Based on the sample size calculation, 48.6 subjects were needed. After extensive recruiting time and effort, 48 subjects consented to participate.

Two other limitations are related to the two independent variables of age and physical activity. The age range in this study only incorporates the ages of a working population, which is approximately between 20 and 60 years. Other studies that found significant proprioceptive changes with age had large differences noted in age range. Skinner et al (1984) found a significant difference with an age range of 20-82, and Kaplan et al (1987) used two convergent groups (under 30 and over 60) to find a significant relationship between age and decreased proprioception. As it is likely that the relationship between age and proprioception is not linear, the limitations of the age range in this study, may not allow for strong conclusions to be made about the relationship between age and posture perception.

The physical activity questionnaire used for this study is not validated. Physical activity was measured as only leisure/sport activities outside of work that illicit a training effect. Occupational factors or domestic activities that are not considered sport, were not included in this study. These two factors could affect the conclusions drawn from the correlations of this variable to the accuracy of perception.

Chapter Two

LITERATURE REVIEW

Introduction to proprioception:

Position sense or proprioception, described as the "sixth sense"(Williams, 1981), consists of sensory information that relates to movements and posture (Cordo et al, 1994). The following sensory receptors are associated with proprioception: muscle spindles, Golgi Tendon Organs (GTOs) , joint afferents, and cutaneous receptors (Cordo et al, 1994). Joint receptors are noted to respond to extreme joint conditions (Beers et al, 1996), indicating increased firing at end range movements. In contrast to this, Bevan stated that active muscle contraction (muscle spindle excitation) versus joint receptor activity results in enhanced conscious perception of movement (Bevan et al, 1994).

Complex Integration of Proprioceptive Information:

Proprioceptive information is not integrated as a linear process, it is integrated in a complex way that leads to enhanced accuracy (Beers et al, 1996). The Central Nervous System (CNS) is continually updated on the relative positions of the body segments by way of static and dynamic proprioceptive signals, tuning the motor system for spatially oriented movements (Bard et al, 1995). Interference when distinguishing position and movement distance takes place at an abstract or conceptual level, rather than a sensory level (Bevan et al, 1994).

The information to the CNS will be different and will be interpreted differently if different biomechanical events take place. Some factors influencing this are: static versus dynamic activities (Bard et al, 1995;Cordo et al, 1995); loaded versus unloaded conditions (Cordo et al, 1995); whether visual guides were used (Bard et al, 1995; Beers et al, 1996); passive versus active movements (Cordo et al, 1995); changes in velocity (Bard et al, 1995); or whether it is a single or multi-joint task (Bard et al, 1995).

Mathews (1988) believes that humans develop complex central maps relating to their body image and position in space. These maps are highly labile and may not be based on what is considered anatomically correct. However, the map can be modified based on observations and these can overrule previous experiences (Matthews, 1988).

The concept of enhancing proprioception through practice and learning, contrasts two other studies. A study by Cordo found some proprioceptive learning in early trials, (up to 35), but no learning effect after that point (Cordo et al, 1995). Chaput and Proteau found that people develop a sensorimotor store in the first 40 trials, but no difference was noted between 40 and 200 trials (Chaput & Proteau, 1996).

Methods of studying position sense:

Often proprioception is tested in two ways: by measuring the threshold for detecting a passive direction change in joint angle; or by reproducing a posture with the contralateral or same limb (Gilsing et al, 1995). Of course, in the spine, there is no contralateral side to mimic. Parkhurst and Burnett (1994) used a spinal motion apparatus to produce passive motion of the spine and measure passive motion threshold, directional motion perception and repositioning accuracy (Parkhurst & Burnett, 1994). The drawback of this method is that the testing was completed in lying and sitting postures, which are not functional postures of work.

Kumar reported an alternate method of measuring postural perception in two studies (Kumar, 1993a; Kumar 1993b). Using 20 male university students as subjects, Kumar compared nine static spinal postures measured photometrically, to free-hand line drawings made by the subjects, and to estimates made on a three dimensional mannequin by the subjects. He found the perception of posture and its reproduction using a mannequin to be accurate and reliable for all sagittal plane movements. The line drawing estimates of angles for stooping in standing (deep forward flexion) were not significantly different from the actual measurements. However, he found a significant difference, when comparing the standing forward bending (shallow forward bend) angles, from line drawings, to those obtained photometrically. The absolute difference in means between the measured and line drawn angle was 4.9 degrees for stooped standing postures and 11.7 degrees for forward bending postures in standing. (Kumar, 1993b). The use of line drawings to estimate spinal posture was shown to have good test-retest reliability (Kumar, 1993a; Kumar, 1993b). With further testing, this tool may have the potential to estimate working postures in a quick, effective, and inexpensive manner.

Tools for measuring spinal motion:

Spinal ROM and movement analysis are common measurements in research. However, a simple objective measurement for measuring spinal motion is still not available (Nordin et al, 1989). Methods of static postural measurement include: modified Schober's test (Fitzgerald et al, 1983; Gill et al, 1988); inclinometers (Gill et al, 1988; Loebl, 1967; Salisbury & Porter, 1986); standard goniometers (Fitzgerald et al, 1983); flexicurve measurements (Burton, 1986); and roentgenograms (Dvorak et al, 1991). Many of these methods have been shown to be valid and reliable (Gill et al, 1988; Burton, 1986; Dvorak et al, 1991; Loebl, 1967). However, these tools only measure static range of motion and many of them cannot be used without interrupting the work environment. Because of this, the application to function and work assessment is not feasible.

Corlett et al (1979) developed a systematic approach to recording working postures, called "postural targeting". This method uses the position of the limbs, torso and head in relation to each other. By direct observation of activities of work, by a trained observer, the predominant and extreme postures are recorded and analyzed using circular diagrams.

Corlett validated this procedure against photometric measurements and achieved correlations of 0.65 or 0.82 for head and trunk posture. (Corlett et al. 1979). Though this system shows validity for trunk postural measurements, it is an extremely time consuming and tedious task.

Dynamic movement and posture have been recorded using various developing technologies. Electrogoniometers or potentiometers allow for recording postures and velocity of movement while an activity is performed (Boocock & Jackson, 1994). Nordin et al (1984) measured movement of the trunk with a flexion analyzer during 60 minute work cycles. Snijders & Van Riel (1987) used this same type of device and measured sagittal plane movements through an eight hour work period. These systems have an advantage of being less cumbersome, but do have potential placement errors and require lengthy calculations and computations to obtain meaningful information.

Photometric techniques are used to evaluate various forms of dynamic or functional tasks. Thurston & Harris (1983) used television/computer motion analysis to analyze the spinal movement during the gait cycle. They found an 8% error when looking at the accuracy of estimating angular measures using this technique over the range of motion observed radiographically. (Thurston & Harris, 1983). Pearcy & Hindle described a three-dimensional analysis system to measure spinal movements in 3 planes and described these movement patterns in this study (Pearcy, 1987).

Marker placement is an important aspect of photometric evaluation of spinal position or movement. One method of marker placement is to use wood or light weight metal pointers, placed on specific spinous processes, perpendicular to the spine (Christie et al, 1995; Thurston & Harris, 1983). Another method of marker placement, more widely used, is to place markers over bony landmarks, on the lateral side of the body and record changes in the angles between these markers (Gill et al, 1988; Winter et al. 1974; Kumar. 1993a; Kumar, 1993b). Kumar used the landmarks of anterior superior iliac spine and glenohumeral joint when analyzing sagittal motion of the spine (Kumar, 1993b). This technique makes a quick and reliable measurement of changes in sagittal posture in the spine.

Factors Affecting the Perception of Posture:

1. Back Pain:

As proprioception and kinesthesis depend on changes in joint, muscle and tendon position (Williams & Warwick, 1980), it is possible for an associated link between back pain and the perception of posture. Abnormal movement patterns and abnormal EMG activity during movement are also noted with low back pain (Tollison & Kriegel, 1989). Parkhurst & Burnett (1984) state that a physiological relationship exists between musculoskeletal injury of the spine and a decreased accuracy of proprioception. In this study, it was indicated that injuries were an influential factor in proprioceptive asymmetry of the spine (Parkhurst & Burnett, 1994). However, in reviewing the literature, it is difficult to discern if decreased postural perception preceded or resulted from a low back pain episode. It is likely that a circular relationship between back pain and the perception of posture exists.

***2. Physical Activity*:**

Postural perception as a component of proprioception requires stimulus to be perceived. The ability to perceive posture depends on the magnitude of the stimulus (Kumar, 1993b). In his study on postural perception in males, Kumar found the more frequently used spinal postures were estimated more accurately than those less frequently used (Kumar, 1993a). Parkhurst and Burnett (1994) stated that repetition is the major shaping force in sensory-motor nervous system. Therefore, it can be hypothesized that when performing activities repeatedly, as in athletics, spinal postural perception will improve.

In a study of spinal proprioception, Parkhurst & Burnett (1994) found that those subjects who exercised more often, responded sooner to position changes and had a greater awareness of passive motion of the spine. This study did not discriminate between trunk exercise and limb exercise, nor did it discriminate between strengthening exercise and aerobic activity (Parkhurst & Burnett, 1994). Another study of proprioception of the knee suggested that large amounts of athletic training lead to superior muscle development and improved proprioception (Barrack et al, 1989).

Jayson (1987) stated that special dynamic forces in the spine are engendered in athletics, gymnastics, ballet-dancing and ice skating. These activities challenge the sensory and perception systems and may increase the adaptive abilities of these systems. In a study of knee proprioception, the proprioception of ballet dancers with hypermobile knees was found to be better than the control group, when testing threshold acuity (Barrack et al, 1989). Contrasting results come from two other studies. Cordo et al (1994) and Chaput and Proteau (1996) state that though there is early learning of proprioception, there is little change after 35(Cordo) or 40(Chaput) trials of the specific activity.

3. Age:

Evidence exists, in the literature, to indicate a decline in joint position sense with age. Skinner et al (1984) supported this hypothesis by studying joint position sense in the limbs of 29 people, ranging in age from 20-82 years. A significant correlation between poor joint position sense and age was found (Skinner et al, 1984). Kaplan et al (1987) compared the joint position sense in the knee, between a group under 30 years to a group over 60 years. He found a lower score in the older group, and suggested the existence of an age-related change in proprioception and static joint position sensation (Kaplan et al. 1987). Age showed a significant relationship in measurements of passive motion threshold and directional motion perception in the spine (Parkhurst & Burnett, 1994).

Summary:

The perception of posture in the spine has been studied by a few researchers, but only in static postures (Kumar, 1993a and 1993b; Parkhurst & Burnett, 1994). Postural perception during dynamic and functional movements has not been studied, as yet, for the spine. In the literature, independent variables of age and athletic activity have been associated with changes in proprioception in the peripheral joints (Skinner et al, 1984; Barrack et al, 1989), as well as the spine (Parkhurst & Burnett, 1994). Parkhurst and Burnett (1994) also described decreased postural perception in the spine, to be related to low back pain. More research is needed to examine the relationship between age, physical activity and back pain and the accuracy of postural perception in the spine.

Chapter Three

RESEARCH METHODS

Study Design:

An observational, descriptive study design was chosen for it can be used to describe the accuracy of perception for this defined population, and determine whether the independent variables such as: age; physical activity; and back pain; influence the accuracy of perception.

Study Participants and Sample Size:

Data was collected on a total of 48 female subjects. Eleven certified nursing assistants, twenty-two nursing home attendants, nine rehabilitation aides and six recreation attendants, at 2 long term care facilities (Macaulay Lodge and the Margaret Thomson Centre, both in Whitehorse, Canada) participated in this study. Based on the job descriptions, these occupations are similar with respect to demands of work. All positions have similar types of working conditions, in that the workers perform frequent patient handling and manual transferring, and that from 90 to 95% of the work time is spent either standing, walking, reaching or bending for all three jobs. The total population of employees in these four positions was 74.

The study was limited to females because of the predominance of women in these professions. Only three employees were excluded from the study based on gender. Using only a few males in our sample, will not give a statistically valid measure of difference between the genders in relation to the perception of posture.

Subjects were first informed about the study at three general staff meetings. After this, lists of all employees working in these four job positions were obtained from the four supervisors. All these employees were sent a letter explaining the procedure (Appendix H) and asking for participation. Compliance was enhanced by the fact that the administrators from both facilities supported this study and allowed employees to take work time to volunteer (Appendix F).

Using a sample size calculation and a Beta level of .2 and a Power level of .8 (Appendix D), the ideal sample size was calculated. The sample size of this experiment was 48 subjects, which was close to the calculated value of 48.6.

Equipment Set-up and Procedure:

Before this study began, a pilot study was done using 7 subjects. This study showed no significant difference between the actual and estimated angles. The results of this study are found in Table 8.

Subjects that agreed to participate signed a written consent form. The experiment was conducted in a laboratory, over the course of 5 weeks. Subjects participated during their scheduled work shifts, most in the middle or end of their shift period. This factor was not standardized.

To measure sagittal movement, sticky fluorescent dots were placed over the subjects left shoulder joint axis and left iliac crest, at the level of the anterior superior iliac spine (ASIS), by the examiner. A fixed shelving unit was set up with a shelf measuring 36 cms from the floor, and a shelf measuring 117 cms from the floor. A metal crate weighing 18 lb., with sandbag included, was placed 22 cms from the back wall. (Appendix E - lab set up) A video-camera was placed on a tripod with the tripod center 355 cms from the back wall and the base of the camera 92 cms off the floor.

The experiment was divided into two sections. For the first part, the subjects were asked to lift the crate from the floor to the top shelf three times. The first two lifts were for practice and the third lift was videotaped. Each subject was asked to lift in her usual manner, at a normal speed and the same way for all three lifts. Subjects were told to consider the position of the markers to each other at two points: when they first took the weight off the floor; and when the weight was placed on the top shelf. After each lift, the crate was returned to the floor by the examiner. Upon completion of the third lift, the subject did two line drawings (Appendix G) for the two lift positions and completed a Visual Analog Scale (VAS) indicating amount of back pain, if any, during the videotaped lift.

For the second section, the subjects were instructed to do the same three lifts. However, for this lift, each subject was asked to consider the position of the markers to each other at one point. This point was when the bottom of the crate passed the lower shelf. Subjects were asked to lift through this point and not stop. After these three lifts were completed, the subject did one line drawing and completed another VAS for that lift. The final task was to complete a questionnaire on age, physical activity and number of years of work (Appendix A).

Data Collection:

The videotaped positions were stopped on the appropriate frame and printed out on a videoprinter. A standard ruler and protractor were used to measure the angles from the line drawings and videoprinted postures. The VAS scale was read using the ruler and the value was entered in the data sheet. To assist in measuring the angles, a horizontal line parallel to the floor surface was drawn through the lower (pelvic) marker. A line connecting the two markers was then drawn and angles measured. Zero degrees was defined as the position when the superior marker is directly above the inferior marker and on the vertical axis. Negative angles indicated positions of extension, whereas, positive angles indicated positions of flexion.

Physical activity level (defined as activity, outside of occupation, that illicits a training effect) was obtained from the questionnaire and this number was divided by 52 to obtain the average hours/week. The data were entered into a computer using SPSS program and statistical analysis was performed.

Statistical Analysis:

Both actual and absolute differences were calculated between the real and estimated angles for the beginning, end and middle position of the lift. Actual differences were calculated by subtracting the estimated angle from the actual angle. A positive number indicated that the subject underestimated the angle or was more flexed than she believed she was. A negative number indicated that the subject overestimated the amount of flexion. The absolute differences were calculated by providing a positive value to all the actual differences. With this, the amount of error was known, but there was no indication about the direction of the error. Descriptive statistics of mean, standard deviation, minimum and maximum values were calculated. A paired t-test was used to compare observed and estimated values, for each of the three positions. Three one-way Analysis of Variance (ANOVAs) were used to determine if there was a significant difference between the direction of error from each position to the other. For all statistical tests an alpha level of 0.05 was set to determined significant results.

For the second objective, the means and standard deviations were used to describe the interval/ratio data of age, physical activity level (average hours/week) and current severity of back pain as measured on the visual analog scale. The relationship of the independent variables to the accuracy of perception was analyzed using Pearson's correlation coefficient (r) on each factor in each position (total of 9 calculations). T-tests to determine the significance of the correlation coefficients were subsequently performed. Demographic data on number of years worked in that position was also described and correlations were calculated for each position with this factor.

Ethics:

The potential subjects were contacted with an initial oral introduction at a general staff meeting. A list of contact names was obtained from the four direct supervisors, and from this list an information letter was given to each potential subject. The supervisors were not informed of who did and who did not participate, so that no pressure was applied on the subjects.

Before the study, a consent form was signed by the participants (Appendix B) and subjects were informed both verbally and on the consent form that they could withdraw at any time, without any adverse consequence to them. During the study, the privacy of subjects was assured by performing the experiment in a separate laboratory, with only the researcher and the participant present. The milk crate contained only 18 lb. for the lift, to minimize any risk of injury during lifting. The results of the study and individual subject scores were kept confidential in a locked storage area and not released to other sources.

Chapter Four

RESULTS

Descriptive Statistics:

The raw data for this study are shown in Table 6-A and Table 6-B. A total of 48 female subjects participated in this study. The mean age of subjects was 36.64 years. The average number of years each employee worked in either of the 4 professions was 7.27 years. The mean for back pain for the two lifts was .34 cms and .29 cms on a scale of 10 cms. It is noted that over 60% of the subjects measured 0.0 in the back pain. The range noted with the remaining 40% was between 0.1 and 8.3 cms (only one individual reporting over 2.5 cms). The average amount of activity in hours per week over the past year was 7.96. Descriptive statistics for the estimated and real angles, as well as the actual and absolute differences for the postural angles is described in Table 7. Descriptive statistics for age, years of work, VAS scores and activity level are presented in Table 1.

Table 1 -Descriptive Statistics for Independent Variables

	Mean	Standard Deviation	Minimum	Maximum
VAS for Lift One (cms)	*.34*	*1.25*	*.00*	*8.30*
VAS for Lift Two (cms)	*.29*	*1.04*	*.00*	*6.9*
Age (years)	*36.65*	*8.67*	*24.00*	*57.00*
Activity level (wks/yr)	*7.96*	*7.58*	*.23*	*42.96*
Years of work (years)	*7.27*	*7.27*	*.04*	*28.00*

VAS= Visual Analog Scale for Pain (10 cm line)

Postural Perception:

A paired t-test was done to establish whether a significant difference was found between the real and estimated postural angles. Using a p value of .05 and 47 degrees of freedom for the beginning and end positions of lift one , a significant difference was found. For the mid position of lift two, only 44 degrees of freedom was used as a videotape error resulted in lost data on 3 subjects. With this third position, significant difference was found between the real and estimated angles, as well.

Table 2 - T-tests for paired samples:

1. Comparing Real and estimated angles for the beginning of lift one.

Paired Differences					
Mean	SD	SE of Mean	t-value	df	2-tail sig
23.96	16.42	2.37	10.11	47	.000

2. Comparing Real and estimated angles for the end of lift one.

Paired Differences					
Mean	SD	SE of Mean	t-value	df	2-tail sig
-9.02	11.53	1.66	-5.42	47	.000

3. Comparing Real and estimated angles for the mid-position of lift two.

Paired Differences					
Mean	SD	SE of Mean	t-value	df	2-tail sig
18.80	12.58	1.88	10.02	44	.000

When analyzing the data, a tendency was seen to underestimate the degrees of flexion for the beginning and mid positions of the lift. There was also a tendency to overestimate the degrees of flexion for the end position. Three one-way ANOVAs with repeated measures were done to determine a significant difference between the direction of error between the 3 positions. Due to the configuration of the data, each ANOVA was performed separately. As the direction of the error was what was being measured here, actual differences were used. A significant difference was noted for all positions, except the within subject effect between the beginning and mid positions (Table 3).

Table 3 - ANOVA of Actual Differences Between Real and Estimated Angles (within subject effects)

1. Comparing Beginning Position to End Position

Source of Variation	S S	DF	MS	F	Sign of F
Within + Residual	8924.49	47	189.88		
Constant	26103.01	1	26103.01	137.47	.000

2. Comparing Beginning Position to Mid Position

Source of Variation	S S	DF	MS	F	Sign of F
Within + Residual	6155.29	44	139.89		
Constant	523.21	1	523.21	3.74	.060

3. Comparing Mid Position to End Position

Source of Variation	S S	DF	MS	F	Sign of F
Within + Residual	7204.6	44	163.74		
Constant	17056.9	1	17056.9	104.17	.000

Correlation of the independent variables:

A Pearson's correlation coefficient (r) was calculated for the relationship of the difference between actual and estimated angles to the three variables of back pain, physical activity and age. A fourth calculation was also done using the variable of number of years of work. The degree of accuracy and not the direction of error was important for this calculation, and therefore absolute error was used. Because the correlation was calculated between the absolute difference and the independent variables, a negative correlation would indicate that accuracy increases with age, physical activity, back pain, or years of work

Table 4 - Pearson's Correlation Coefficients between Absolute difference and Independent Variables

	Age (years)	**Back pain** (cms)	**Physical activity** (hrs/week)	**Years of work** (years)
Beginning of Lift 1 (Absolute Diff)	*-.0624* *(48)* *P=.673*	*-.0266* *(48)* *P=.858*	*-.2255* *(48)* *P=.123*	*-.1288* *(48)* *P=.383*
End of Lift 1 (Absolute Diff)	*-.2985* *(48)* *P=.039*	*.1049* *(48)* *P=.478*	*-.0037* *(48)* *P=.980*	*-.2078* *(48)* *P=.156*
Mid Position of Lift 2 (Absolute Diff)	*-.1373* *(45)* *P=.368*	*.0173* *(45)* *P=.910*	*-.0149* *(45)* *P=.923*	*-.4248* *(45)* *P=.004*

Scatterplots illustrating the correlations are shown in Figures 1-3.

It is noted, that the pilot study (Table 8) correlations were calculated using accuracy, and therefore a positive correlation will be interpreted as a positive correlation.

Figure 1: Scatterplot of Pearson's correlation between absolute difference in beginning position and activity level

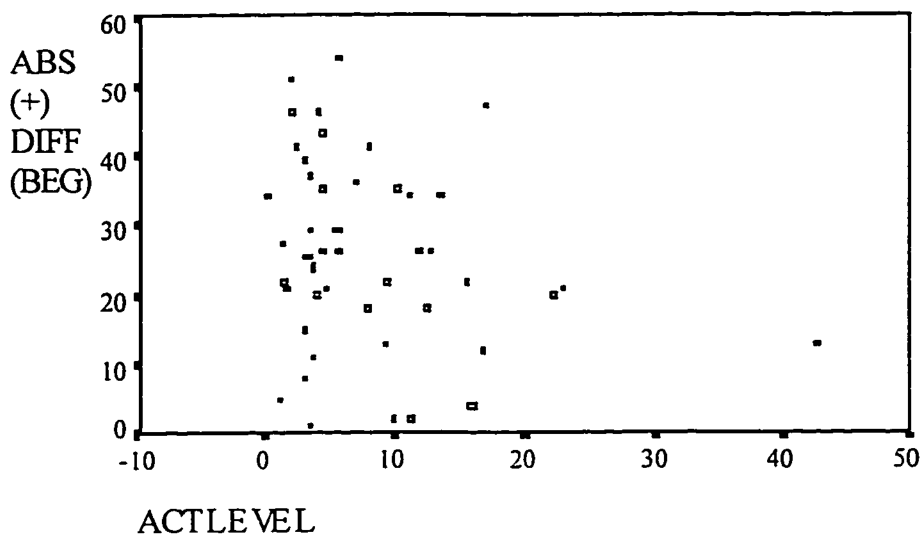


Figure 2: Scatterplot of Pearson's correlation between absolute differences in end position and age

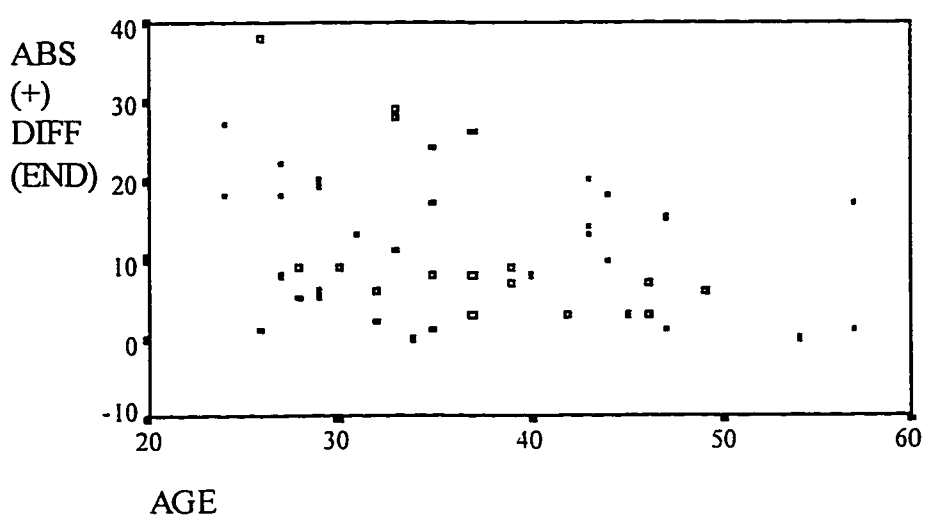
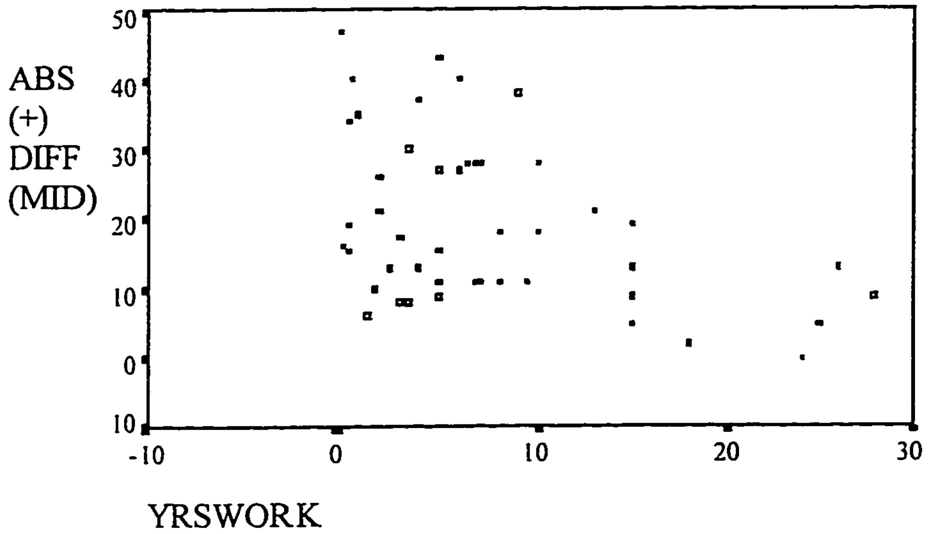


Figure 3: Scatterplot of Pearson's correlation between absolute difference in mid position and years of work



When examining the t-values for significance of the correlation coefficients (Table 5), it is noted that only the relationship between age and the absolute difference at the end position (Figure 2); and years of work and the absolute difference at the middle position (Figure 3) were significant. This was determined by using the significance level of 0.05 which indicates all critical values above (-) 1.684 are significant.

Table 5 - t value calculations for significance of Pearson's correlation coefficient

	Age (years)	**Back pain** (cms)	**Physical activity** (hrs/week)	**Years of work** (years)
Beginning of Lift One (Absolute Diff)	*t= -0.424 (n=48)*	*t=-0.181 (n=48)*	*t=-1.570 (n=48)*	*t=-0.881 (n=48)*
End of Lift One (Absolute Diff)	*t=-2.120 (n=48)*	*t=0.712 (n=48)*	*t=-0.025 (n=48)*	*t=-1.441 (n=48)*
Mid Position of Lift Two (Absolute Diff)	*t=-0.909 (n=45)*	*t=0.113 (n=45)*	*t=-0.098 (n=45)*	*t=-3.077 (n=45)*

Chapter Five

DISCUSSION

Generalizability of the Population:

Forty-eight long-term care workers participated, from a population of 74, giving a 65% compliance rate. This sample represented a wide range of ages (24-57 years) and experience levels (.04-28 years). No data is available on age, physical activity or back pain of the non-volunteers (35% of population), so it is impossible to assess differences between the two groups. In a study on cumulative load as a risk factor for health care aides, Kumar stated that 91.3 % of his subjects were females (Kumar, 1990). Laflin reported that 84% of injured workers in a tertiary care unit were females (Laflin, 1994). Similarily, in this study, the work force was predominantly female. Only three male health care workers were excluded.

There was little variability in back pain scores, with over 60% of participants scoring 0.0 on the VAS scale for both lifts. One limitation may be, that there is more variability in back pain in most health care populations. Three potential subjects reported that they did not participate, due to pain. Thus, the population may not be representative with respect to back pain.

The Accuracy of the Perception of Posture:

This study found significant differences between the actual and estimated angles of sagittal plane motion for the beginning, end and mid positions in a dynamic lift. Because of this result, we are unable to draw any conclusions about the tool validity. Whether the negative result is the nature of the tool itself and it's use; or is due to the fact that this population was not able to perceive posture accurately, is uncertain.

The first explanation to the significant difference found between the actual and estimated postures, is that the subjects could not perceive the actual posture during the lift. This explanation appears to be more likely, considering that no significant difference was found between actual and estimated angles, when using this tool with some static spinal postures (Kumar, 1993b); and when using the tool with the same protocol in another population (Pilot study*- Table 8).

Comparing this study to Kumar's study (1993b): we have added the elements of the task itself with the cognitive aspects of material handling, as well as loading of the spine, and thereby increased the complexity of the task. The amount of information that is inputted into the sensory and motor systems is also increased. It is possible that perceiving posture in a static position is possible, and yet is not possible when the posture is to be perceived at a point in a dynamic movement. However, it should be noted that in the pilot study* (Table 8) the exact movements and postures were tested with the opposite result. The difference noted between the two subject groups is the type and amount of education and training. Though other health care workers, especially support workers, do undergo a lot of postural stress and do frequent lifting and handling tasks, they are not required to analyze and quantify these activities. The analysis of movement and activity is a large part of physical and occupational therapists' job function. The subjects in Kumar's studies (1993a, 1993b) were University medical students and therefore varied in the type and level of education from this study's population, as well.

If it was assumed that the line-drawing tool measures postural perception correctly, but the subjects were perceiving it inaccurately, the results would still show a significant difference between actual and estimated angles. Testing the reliability of the tool in a test-retest situation could assist in evaluating this. If the subjects estimated the same posture in the same way, albeit inaccurately, for repeated measures, this would indicate that the tool was reliably measuring the subjects perception. Further study, testing the reliability in specific postures is warranted, and would shed further light on the assumption that this population was unable to perceive the spinal sagittal plane postures accurately.

The Line-drawing Tool:

The second explanation for the difference noted between actual and estimated postures in this study is that the line-drawing tool is not a valid measurement tool for the perception of spinal posture in dynamic lifting. The results can be compared to the findings by Kumar, when he used 20 male University students as subjects. In his study, the line-drawing tool proved to be an accurate and valid measure for the forward stooped positions, but not for standing forward bending postures (Kumar, 1993b). The tool showed good test-retest reliability for all sagittal postures. This may indicate that subjects used the tool in the same way each time, but could not accurately estimated posture for the position of forward bending. A pilot study* for this project, with 6 female physical therapists and 1 female occupational therapist as subjects, and using identical protocol, found no significant difference between real and estimated angles for the beginning and mid positions of the lift. A significant difference was found for the end position of the lift (Table 8). With these two studies in mind, it appears that this particular self line-drawing tool, has been used to accurately estimate some spinal sagittal plane postures.

If it is assumed that the subjects can perceive their posture, and this tool is not measuring it accurately, the question is why? In comparing the study by Kumar (1993b) to this project, one obvious difference stands out. This study was measuring points in a dynamic movement, whereas Kumar looked at static positions. Adding the complexity to the task may make the illustration of posture inaccurate. Two other differences are noted between this study and the two studies by Kumar (1993a; 1993b), and these were: the subjects in Kumar's studies were all male and all University medical students. Whether there is a difference in postural perception and illustration of this posture related to gender is impossible to determine by comparing these studies. It may also be possible that the amount and type of education that the students in Kumar's studies receive may enhance the ability to illustrate postures.

With the pilot study* results (Table 8), the subjects doing identical protocol were able to accurately estimate postures using this tool. Though this pilot only included seven subjects, the difference noted between the two populations is the type and amount of education, and nature of work that the two groups do. It may be possible that the use of the tool requires a type of conceptual thinking and illustration of that concept. The recording of proprioceptive abilities is part of everyday work to both these occupations. The type of training and education that physical and occupational therapists receive could therefore enable them to use the tool accurately.

If it is assumed that the line-drawing tool is not accurately estimating posture, then it may be possible with training that subjects could be taught to use it accurately. Cordo et al (1994) and Chaput & Proteau (1996) found that though some motor learning takes place with initial practicing (35 and 40 trials respectively), and that practice beyond that resulted in no increases in learning. Using a method of verbal and visual correction for several trial could possibly result in teaching the use of the tool. This is again assuming that the subjects can perceive spinal posture and that the inaccuracy is a result of the tool.

If it can be shown that this tool is a reliable measurement and through teaching, it becomes valid, it could be very useful. This tool could be used to estimate the postures at work in a quick and easy way. The estimated postures could then be used to assist in activity analysis and analysis of load and stress on the human body related to work conditions. In large industrial settings, an effective and quick tool such as this, could be widely used to measure repetitive or sustained postures. This would require testing in other work conditions and occupations.

Correlation of the independent variables:

1. ***Back Pain:***

There was no correlation found between accuracy of postural perception, in all 3 positions, and back pain. The Visual Analog Scale (VAS) is used to measure the severity of pain at the present time, though in this study it was noted that many subjects had no pain with the lifting activity. Over 60% of the VAS scores in all three lifts were 0.0. When comparing these results to the pilot study* (Table 8), a correlation was found between the accuracy in the beginning position and increased back pain. This may mean that in this position, accuracy increases as back pain increases. No correlation in the middle and end position accuracy to back pain was found. Again, very little variability in the VAS scores was found in this sample.

Whether back pain enhances or decreases postural perception cannot be determined from this study. Further study comparing a back pain group to a non-back pain group may lead to further clarifications. An alternate measurement to the VAS would be useful to thereby measure the presence or absence of pain.

2. ***Physical Activity***

No significant correlations were found between physical activity and the accuracy of perception for the three positions of the lift. It was hypothesized that an increased motor input and movement activities, would enhance proprioception. Studies by Jayson (1987), Parkhurst &Burnett (1994) and Barrack et al (1989) support this hypothesis by stating that challenging and developing the sensory and motor systems with physical activity and sport, leads to increased adaptive abilities and improved proprioception. The results of the pilot study* (Table 8) also support this hypothesis, as a relationship was found between the accuracy of perception of lift posture of the dynamic lift and physical activity levels; and a correlation between the beginning lift posture perception accuracy and physical activity was also apparent.

This study did not find that physical activity enhanced proprioception. The results of the study support those of Cordo et al (1994) and Chaput (1996) who indicated that proprioception does not improve significantly with extensive practice.

The use and validity of the tool to measure physical activity is also in question. This questionnaire includes all activities outside of work and domestic activities, that illicit a training effect. Separating specific activities that require exceptional proprioceptive abilities may lead to higher resolution in results. A tool of this type has yet to be quantified and validated.

3. Age:

The literature commonly reports that as age increases, proprioceptive abilities decrease (Kaplan et al, 1987; Parkhurst & Burnett, 1994; Skinner et al, 1984). The pilot study* (Table 8) did not support this, as a correlation was found between accuracy in the beginning position and increased age; and a correlation was found between accuracy in the end position and increased age. These pilot study results, though they used a small sample size, indicate a trend toward improved accuracy with age. A relationship likely exists between age and experience and this may be a confounding variable.

In our study a small, but significant relationship was also found between accuracy at the end position and increased age. No correlation was found for the other 2 positions. It was hypothesized that accuracy would decrease with increasing age, but this study had the opposite findings. The relationship between age and years of work may be a factor. With increased age, comes increased experience and possibly enhanced postural perception.

The limitations of this study related to the range of ages used, could also be a factor. As this was a working population, the age range was 24 to 57 years. Skinner et al (1984) studied an age range of 20-82 and found significant correlation with increased age and decreased proprioception. The results from this study do not lead to any conclusions about the relationship of age and spinal postural perception. Again, further study comparing two groups distinguished by age, such as that by Kaplan et al (1987), could lead to more conclusions.

4. Years of work:

Data on years of work was originally collected as demographic information. However, a significant correlation was found between years of work and the accuracy of postural perception, in the mid position. This variable was not assessed in the studies by Kumar (1993a, 1993b) or in the pilot study (Table 8), so no comparisons are possible. Those long term care workers who have worked for several years and have not injured themselves, may have higher innate or learned proprioceptive abilities. This conclusion would support the existence of a "training effect" and the belief that proprioception can be learned.

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* The pilot study had a total sample of 7 subjects.

Chapter Six

CONCLUSION

For this population of workers, it was shown that spinal postural perception cannot be accurately estimated using the line-drawing tool. A significant difference was found between the estimated and actual postures for all three moments in a dynamic lift. Whether the subjects could not perceive their posture or the inaccuracy was a result of the tool itself, is uncertain. Further study in this area is needed, because if this method is proven valid, it will be a quick and easy way of assessing work postures, and could be expanded to an industrial population.

No consistent correlations were found between back pain, physical activity, age, years of work, and the accuracy of postural perception in all three postural positions of a dynamic lift. Only two correlations of the twelve reached significance. Limited variability in outcomes for back pain and age make it impossible to make conclusions about these variables. Also, the tool for measuring physical activity was not validated and this limits conclusions drawn from the results of this variable. If a valid and reliable tool can be developed, further study comparing convergent groups with marked variations in these factors, could lead to more definitive information.

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APPENDIX A

Subject Questionnaire

Name:__________________________ Age:__________________________

Combined number of years as CNA, NHA,Rehab Aide, or Rec Attend: __________

Please check the activity or activities in which you have participated over the past year. Indicate the average number of hours per week and number of weeks per year that you participating in these activities outside of your employment and activities of daily living. The activities should give a training effect (increased cardiovascular fitness, increased muscle strength or endurance, increased flexibility).

__ volleyball ___ hours/wk ___ weeks/year
__ basketball ___ hours/wk ___ weeks/year
__ football ___ hours/wk ___ weeks/year
__ aerobics/fitness class ___ hours/wk ___ weeks/year
__ ballet/dance ___ hours/wk ___ weeks/year
__ walking/hiking ___ hours/wk ___ weeks/year
__ skating/hockey ___ hours/wk ___ weeks/year
__ yoga/tai chi ___ hours/wk ___ weeks/year
__ skiing ___ hours/wk ___ weeks/year
__ baseball/softball ___ hours/wk ___ weeks/year
__ weightlifting ___ hours/wk ____ weeks/year
__ running/jogging ___ hours/wk ___ weeks/year
__ gymnastics ___ hours/wk ___ weeks/year
__ swimming/aquasize ___ hours/wk ___ weeks/year
__ martial arts ____ hours/wk ___ weeks/year
__ biking ___ hours/wk ___ weeks/year
__ other ___ hours/wk ___ weeks/year ?describe activity __________________

APPENDIX B

Consent Form

Title: The accuracy of perception of back posture during dynamic lifting.

Investigator: Liris Smith, Physical Therapist, Graduate student, Dept. Of Physical Therapy, University of Alberta, 403-633-6711.

Shrawan Kumar, PhD., Professor, Dept. of Physical Therapy, University of Alberta, 403-492-5983.

Purpose: The purpose of this project is to assess the accuracy of the perception of spinal posture in certified nursing assistance, nursing home attendants, rehabilitation aides and recreation attendants when performing a lifting task. The effects of back pain, age, and physical activity on the accuracy of perception will also be studied.

Procedure: You will be asked to answer a short questionnaire about age, low back pain history, and physical activity levels. You will also be asked to perform, a lift with 18 lbs from the floor to shoulder height three times, while being videotaped. This procedure will be repeated two times. There is a minimal risk of muscular strain. Markers will be placed on the top of the pelvis and the shoulder. As these areas need to be exposed for photography, you are requested to wear a sleeveless shirt and shorts with the top of the pelvis and shoulder exposed for marker placement. The time required to do all the procedures will be approximately 15-20 minutes.

Consent:

I, ____________________________, agree to participate in the above named study.
I understand my participation is voluntary and I may withdraw from the study at any time without consequences. I recognize that I may not necessarily benefit personally from this study.

Information stored on videotape and paper will be kept confidential and stored in a locked file. I understand that the videotape of the lifting procedure will be stored for 5 years, due to U of A regulations. My name will not be associated with any publication arising from the research.

I am free to ask any questions of the researcher at any time.

______________________	______________________
Participant's signature	Date
______________________	______________________
Researcher's signature	Date
______________________	______________________
Witness' signature	Date

APPENDIX C

Visual Analog Scale

No Pain |————————————————————| Extreme Pain

Please estimate the amount of back pain you experienced during the videotaped lift by marking a vertical line on this scale.

APPENDIX D

Sample Size Calculation For Independent Variables

With a total explained variance value set at 0.2, an alpha level of 0.05 and a study power of 0.80, and using 3 independent variables, L= 10.9 (Warren, 1992).

$$\text{total } n = \frac{L}{f^2} + k + 1 \qquad \text{where } f^2 = \frac{R^2}{1-R^2} \qquad (k = \#\text{ of independent variables})$$

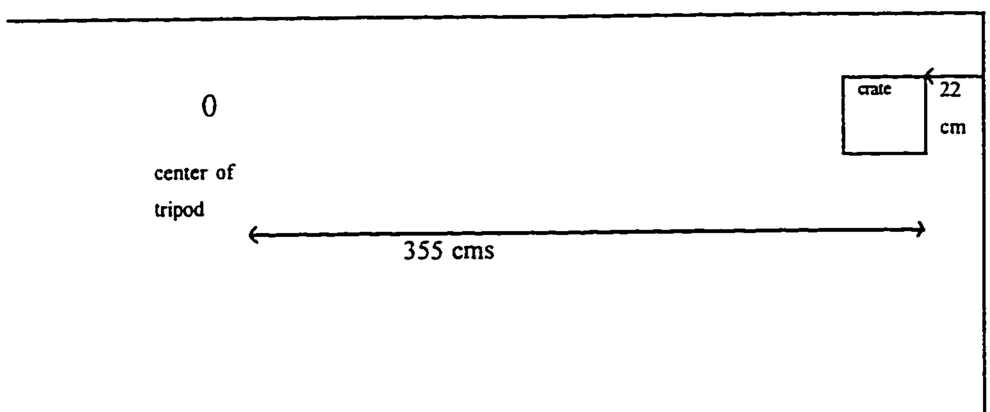
$$\text{total } n = \frac{10.9}{0.25} + 4 + 1 = 48.6 \text{ subjects}$$

Therefore, in order to find a 0.2 variance at the alpha level of 0.05 and a power of 0.8, approx. 49 subjects are needed.

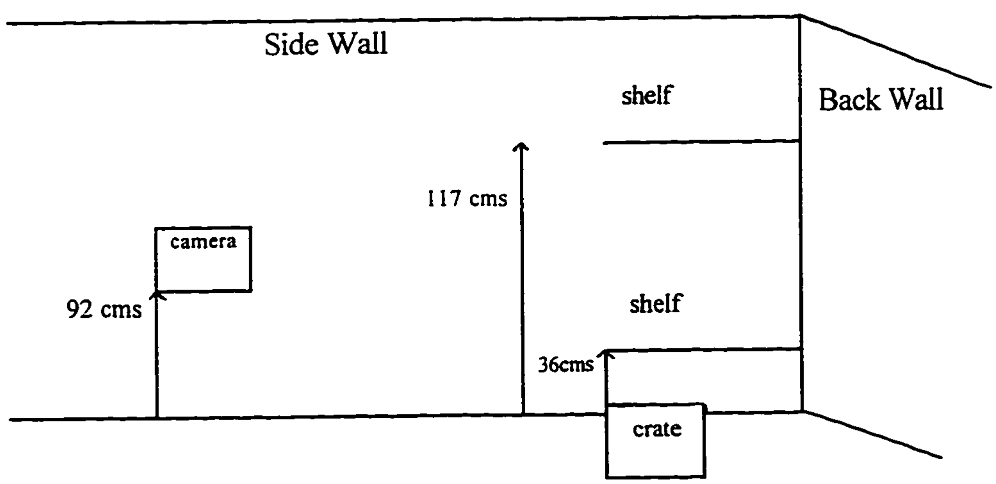
APPENDIX E

Camera And Lab Set-Up

OVERHEAD VIEW



SIDE VIEW



APPENDIX F

Letter of Support

Date:	97/05/14	
To:	ALL STAFF - CONTINUING CARE	
CC:	Pauline Snell	Laurie Rear
	Ann Marie Dillon	Sharon Haave
	Kjell Denhoff	
From:	ADMINISTRATOR - THOMSON CENTRE	
Subject:	RESEARCH PROJECT	

Liris Smith (Thomson Centre physical therapist) will be beginning a research project shortly and requires the assistance of volunteers from Macaulay Lodge and the Thomson Centre.

The Department of Health and Social Services supports both the project and Liris in her academic achievements. Anyone that volunteers to participate will be encouraged to do so while at work. Please just make your supervisor aware of the fact that you will need this time.

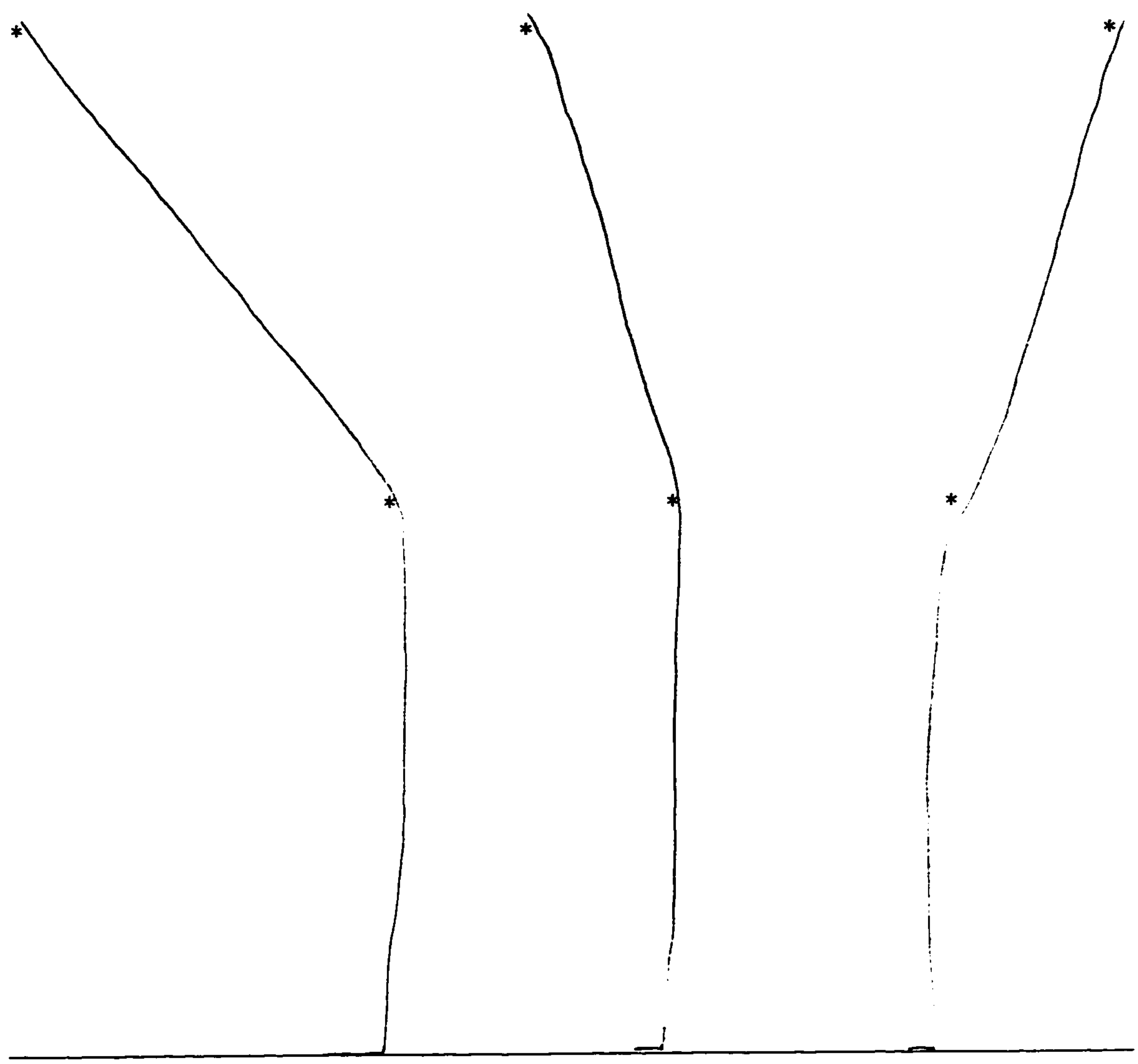
Please give this your serious consideration. Liris has invested a lot of time into graduate program and needs this research to complete her degree.

We are VERY proud of Liris.

Please give her your support.

APPENDIX G

Sample Line Drawings



APPENDIX H

Letter to Subjects

To: «FirstName» «LastName»
«Title»
From: Liris Smith
M.Sc.P.T. Candidate
University of Alberta
Edmonton, Alta.
Re: Research and Volunteer Subjects

I am working presently as a physical therapist for the Thomson Centre and towards a research and thesis based Master's in Physical Therapy. As a part of my graduate work I am performing an observational study of the perception of posture in the low back in female CNAs, NHAs, Rehab Aides and Rec Attendants. The proposal for this research has been presented and successfully defended at the University of Alberta, including the approval of ethics.

I am requesting volunteers to participate as subjects for the study. This would require approximately 20 minutes of your time. You will have the support of YTG (see attached letter) to participate on your scheduled work-time. The study would involve lifting a 19 lb crate from the floor 6 times and being videotaped for two of those lifts. It would also involve completing a questionnaire on back pain, activity level and age.

Participation in this study is strictly voluntary and you are under no obligation to participate. The names of those people participating will not be released to the supervisors. The analysis of all the data collected will be available to the facility upon completion of the study, though specific data on each subject is kept confidential.

Please complete the attached form and return to me in the envelope provided via the YTG internal mail system. Thank-you for considering your participation.

____
Liris Smith, B.Sc. P.T., M.Sc.P.T. Candidate

Table 6-A

Raw data

Subj #	RL beg	EstL beg	RL end	EstL end	RL mid	EstL mid	VAS 1	VA S2	Act level	Age	Yrs work
1	54	55	11	29	39	22	0.0	0.0	3.50	44	3.0
2	32	12	-5	6	36	20	0.2	0.4	4.00	33	.25
3	48	22	6	3	47	20	0.0	0.0	11.96	42	5.0
4	24	22	2	-3	28	19	0.0	0.0	9.85	28	5
5	32	-2	-9	1	22	9	0.3	0.5	.23	44	26
6	35	17	8	16	32	13	8.3	6.9	12.5	27	.58
7	87	52	-3	35	61	35	2.5	2.4	4.42	26	2
8	70	33	5	-8	47	9	0.0	0.0	3.4	43	9
9	26	55	-7	17	28	-2	0.0	0.0	5.31	35	3.5
10	33	11	-1	5	32	19	0.2	0.2	9.5	32	15
11	72	29	-1	0	44	39	0.0	0.0	4.31	57	15
12	30	4	-8	0	16	1	0.0	0.0	5.69	40	.5
13	60	9	11	4	40	31	0.4	0.7	1.85	46	15
14	29	25	-3	26	28	17	0.5	0.2	15.92	33	9.5
15	52	39	-6	22	42	34	0.0	0.0	42.69	33	3
16	56	41	-8	9	46	18	0.0	0.1	3.0	35	6.5
17	66	54	2	11	44	31	0.1	0.1	16.67	28	4
18	74	20	-4	1	59	38	0.0	0.0	5.54	28	2
19	20	9	-12	-6	12	12	0.0	0.0	3.56	49	24
20	19	1	11	2	12	4	0.2	0.1	7.96	39	3.5
21	45	19	-14	12	31	10	0.0	0.0	4.46	37	13
22	54	15	1	1	25	6	0.0	0.0	2.98	54	15
23	62	67	7	6	27	22	0.0	0.0	1.11	47	25
24	32	6	-6	-1	29	18	0.0	0.0	12.92	29	7

Subj= subject number RL-= real angle EstL = estimated angle VAS= Visual Analog Scale (cms)

Table 6-B

Raw data (continued)

Subj #	RL beg	EstL beg	RL end	EstL end	RL mid	EstL mid	VAS 1	VAS 2	Act level	Age	Yrs work
25	42	22	4	5	30	20	0.0	0.1	22.16	26	1.8
26	46	0	-2	16	50	16	0.2	0.2	2.15	24	.5
27	69	28	9	27	47	32	0.1	0.0	2.42	27	5
28	51	26	-9	8	53	13	0.2	0.1	3.15	57	.7
29	60	13	1	2	54	17	0.0	0.0	16.9	35	4.0
30	25	12	-7	13	23	10	0.0	0.0	9.36	43	2.5
31	19	27	12	-3	13	4	0.0	0.0	3.0	47	28
32	79	38	-3	17	60	33	0.0	0.0	8.12	29	6
33	63	28	4	4	52	12	0.0	0.0	10.23	34	6
34	42	17	-6	0	41	13	1.2	0.1	3.27	29	7
35	81	45	-8	2		8	0.0	0.0	7.0	44	5
36	34	13	-5	-2	23	15	0.0	0.0	4.67	37	3
37	46	24	7	4	38	20	0.0	0.1	15.69	46	8
38	48	27	-2	5	35	7	0.0	0.0	23.04	39	10
39	43	14	1	23		48	0.3	0.4	5.58	27	.04
40	41	20	3	11	34	36	0.5	0.6	1.69	37	18
41	56	54	-4	9	41	47	0.0	0.0	11.27	31	1.5
42	72	26	0	27	62	15	1.0	0.6	4.13	24	.17
43	44	15	-1	8	39	28	0.1	0.2	3.46	30	8
44	57	33	5	19	40	29	0.1	0.0	3.54	43	5
45	64	37	-6	13	59	41	0.0	0.0	1.38	29	10
46	21	-1	-7	1		-2	0.0	0.0	1.42	35	.5
47	49	15	2	4	43	8	0.0	0.0	11.23	32	.92
48	57	23	7	4	43	0	0.0	0.0	13.69	45	5

Subj= subject number ***RL-= real angle*** ***EstL = estimated angle*** ***VAS= Visual Analog Scale (cms)***

Table 7

Descriptive Statistics for Actual and Absolute Differences between Real and Estimated Postures (measured in angular degrees)

	Mean	Standard Deviation	Minimum	Maximum
Real Angle for Beginning of Lift 1	*48.35*	*17.87*	*19.00*	*87.00*
Estimated Angle for Beginning of Lift 1	*24.40*	*16.44*	*-2.00*	*67.00*
Actual Differences for Beginning of Lift 1	*23.96*	*16.42*	*-29.00*	*54.00*
Absolute Differences for Beginning of Lift 1	*25.75*	*13.36*	*1.00*	*54.00*
Real Angle for End of Lift 1	*-.58*	*6.57*	*-14.00*	*12.00*
Estimated Angle for End of Lift 1	*8.44*	*9.93*	*-8.00*	*35.00*
Actual Differences for End of Lift 1	*-9.02*	*11.53*	*-38.00*	*15.00*
Absolute Differences for End of Lift 1	*11.48*	*9.02*	*.00*	*38.00*
Real Angle for Mid Position Lift 2	*37.93*	*13.33*	*12.00*	*62.00*
Estimated Angle for Mid Position Lift 2	*19.06*	*12.79*	*-2.00*	*48.00*
Actual Difference for Mid Position Lift Two	*18.80*	*12.58*	*-6.00*	*47.00*
Absolute Differences for Mid Position Lift 2	*19.19*	*12.02*	*.00*	*47.00*

Table 8 - Pilot Study Results

Table 8-A: Raw Data and Descriptive Statistics for Beginning of Lift 1

	Actual angle (degrees)	Estimated angle(degrees)	Pain (cm)
1	28	41	0
2	27	22	0
3	25	9	0
4	27	26	0
5	15	16	3.9
6	19	20	.1
7	28	39	0
Mean	24.14	24.71	0.57
SD	5.11	11.71	1.47

Table 8-B: Raw Data and Descriptive Statistics for End of Lift 1

	Actual angle (degrees)	Estimated angle(degrees)	Pain (cm)
1	-7	13	0
2	-1	12	0
3	-9	12	0
4	-8	11	0
5	0	-8	3.9
6	0	12	.1
7	-16	11	0
Mean	-5.86	9.00	0.57
SD	5.93	7.53	1.47

Table 8-C: Raw Data and Descriptive Statistics for Middle of Lift 2

	Actual angle (degrees)	Estimated angle(degrees)	Pain (cm)
1	19	29	0
2	29	13	0
3	23	13	0
4	24	24	0
5	12	11	3.5
6	16	14	.1
7	27	31	0
Mean	21.43	19.29	0.51
SD	6.08	8.46	1.32

Table 8 - Pilot Study Results
Continued

Table 8-D: Raw Data and Descriptive Statistics for Age and Activity Level

	Age (years)	Activity Level (Hours/Week)
1	41	11.87
2	28	19.54
3	33	10.65
4	28	1.38
5	32	10.10
6	36	2.92
7	34	7.50
Mean	33.14	9.14
SD	4.56	6.06

Table 8-E: Comparing Actual and Estimated Angles (degrees)

	True Diff. (Beg Lift 1)	Absolute Diff. (Beg Lift 1)	True Diff. (End Lift 1)	Absolute Diff. (End Lift 1)	True Diff. (Mid Lift 2)	Absolute Diff. (Mid Lift 2)
1	-13	13	-20	20	-10	10
2	5	5	-13	13	16	16
3	16	16	-21	21	10	10
4	1	1	-19	19	0	0
5	-1	1	8	8	1	1
6	-1	1	-12	12	2	2
7	-11	11	-27	27	-4	4
Mean	-0.57	6.86	-14.86	17.14	2.14	6.14
SD	9.76	6.39	11.28	6.47	8.61	5.96

Table 8-F: Paired T-test comparing actual to estimated angles (degrees).
i. Beginning of Lift one

At 6 df and using a p at .05 level of significance, using a one-tailed test, a significant difference is found if the t value is at or over 1.943.

t = -0.15

* No significant difference was found between the actual and estimated angles.

Table 8 - Pilot Study Results
Continued

ii. End of Lift One

At 6 df and using a p at .05 level of significance, using a one-tailed test, a significant difference is found if the t value is at or over 1.943.
t = -3.49
* A significant difference was found between the actual and estimated angles.

iii. Middle of Lift Two(dynamic)

At 6 df and using a p at .05 level of significance, using a one-tailed test, a significant difference is found if the t value is at or over 1.943.
t = 0.66
* No significant difference was found between the actual and estimated angles.

Table 8-G: Pearson's correlation coefficient to show the relationship between accuracy and the 3 variables of age, pain, and physical activity.

i. Beginning of Lift One

	Age	**Pain**	**Exercise**
Accuracy	r = 0.46	r = 0.42	r = 0.35

ii. End of Lift One

	Age	**Pain**	**Exercise**
Accuracy	r = 0.21	r = -0.059	r = - 0.16

iii. Middle of Lift Two

	Age	**Pain**	**Exercise**
Accuracy	r = 0.018	r = -0.05	r = 0.88