Memorandum

Date: March 25, 2002

From: Michael J. Galvin, Jr., Ph.D., Lead Program Activity
Office of Extramural Programs, NIOSH, D30

Subject: Final Report Submitted for Entry into NTIS for Grant 5 R01 OH003400-03.

To: William D. Bennett
Data Systems Team, Information Resources Branch, EID, NIOSH, P03/C18

The attached final report has been received from the principal investigator on the subject NIOSH grant. If this document is forwarded to the National Technical Information Service, please let us know when a document number is known so that we can inform anyone who inquires about this final report.

Any publications that are included with this report are highlighted on the list below.

Attachment
cc: Sherri Diana, EID, P03/C13

List of Publications

Lu ML: The Effect of Fatigue on Electromyography Activity Patterns While Performing Tasks on Inclined Surfaces. PhD. Dissertation. Universtiy of Cincinnati, 2001

Mangaharam, J: The Effects of Muscular Fatigue on Dynamic Motion of Whole Body Center of Gravity. M.S. Thesis. University of Cincinnati, 2001

Mangharam J, Bhattacharya A, Succop P, Bagchee A: The Effects of Lower Limb Muscular Fatigue and Work Experience on Patterns of Falling in Workers. (pages 1-16); Published in Straker, L and Pollock, C., (Eds) 1999.CD-ROM Proceedings of Cyberg 1999: The Second International Cyberspace Conference on Ergonomics. The International Ergonomics Association Press, Curtin University of Technology, Perth, Australia. ISBN 0 9577485 0 7.

Kincl L, Yu N, Bagchee A, Mitchell T, Bhattacharya A, Succop P: The Effect of Workload and Wxperience in Industrial Workers While Working on Inclined Surfaces on Visual Spatial Perception. 15th International Soc. For Occupational Ergonomics and Safety Conference, Fairfax, VA, June 4-7, 2001

Title: Effect of Workload on Task Perfomance on Inclined Surfaces
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Telephone: (513) 558-2263
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Abstract:
This study provides an experimental design for investigating the main effects and interaction between fall risk factors associated with task performance on inclined surface on workers' postural balance, postural muscle contraction patterns and eye movement patterns. The risk factors studied were standing surface inclination, job-task type, and experience in working on inclined/elevated surfaces, physical fatigue, and lack of visual cue in the environment. In this study, postural instability and propensity of loss of balance due to fall risk factors were evaluated for 82 industrial workers' performance (20 to 58 years of age) on test conditions, which represent combinations of these risk factors. This study addressed the following questions: (a) How do work surface inclination and muscle fatigue affect postural balance and postural muscle contraction patterns and eye movement patterns? (b) Do workers with experience in working on inclined surface have better visual spatial perception than those with no experience and © Does an experienced worker utilize his/her visual environment differently than the inexperienced worker in maintaining better postural balance during task performance on inclined surface? Results obtained from this study with industrial worker subjects now provide the basis for future prospective studies using a larger sample to determine the impact of training programs for improving postural balance of inexperienced workers working on incline surfaces. The results obtained from this study will now help enhance our existing statistical model showing the relationship between postural stability and propensity of loss of balance and the independent variables characterizing the experience, muscle fatigue, job-task type, visual cue and personal risk factors. The significant findings from this study are given in the previous Section.

Publications

Kincl L, Yu N, Bagchee A, Mitchell T, Bhattacharya A, Succop P: The Effect of Workload and Wxperience in Industrial Workers While Working on Inclined Surfaces on Visual Spatial Perception. 15th International Soc. For Occupational Ergonomics and Safety Conference, Fairfax, VA, June 4-7, 2001

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FINAL PERFORMANCE REPORT

Laboratory: Biomechanics-Ergonomics Research Labs
and
Epidemiology/Biostatistics Division
Department of Environmental Health
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"Workload Effect on Task Performance on Inclined Surfaces"

RO1-OH03400

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Date: 12/31/01

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LIST OF ABBREVIATIONS

ACTIVITY: Average number of hours per week spent working on an elevated or inclined surface

ANCOVA: Analysis of covariance

AP: Anterior-Posterior

APDF: Amplitude probability density function

A_{sb}: Area of the FSB

A_t: Area of stabilogram

BOSA or BOS: Base of supporting area

CG or COG: Center of Gravity

CP or COP: Center of Pressure

EMG: Electromyography

EXP: experience (0 or 1)

EXP_JOB: Months working on an elevated or inclined surface

FSB: Functional Stability Boundary

Fx: Horizontal force in the x-direction

Fy: Horizontal force in the y-direction

Fz: Vertical force

GLM: General linear model

HR: Heart rate

$HR_{resting}$: Resting heart rate

HR_{max}: Maximum estimated heart rate

IPSB: Index of Proximity to Stability Boundary

LG: Left Gastrocnemius

LH: Left Hamstring

LQ: Left Quadricep

LT: Left Tibialis

MF: Median frequency

ML: Medio-lateral

MVC: Maximum voluntary contraction

p: Minimum distance between the stabilogram and the FSB

PE: perceived exertion

PSOF or PSOS: Perceived Sense of Slip or Fall

RG: Right Gastrocnemius

RH: Right Hamstring

R_{max}: Radial distance of the point on the FSB that is closest in proximity to the CP

RMS: Root Mean Square

RQ: Right Quadricep

RT: Right Tibialis

SAR: Sway Area Ratio

SA: sway area

SEM: structural equation model

SL: sway length

TSB: Theoretical Stability Boundary

VSP: visual spatial perception

WRTI: Weighted Residence Time Index

z^i: Fraction of time spent in the proximity of zone i.

--slope: slope of that muscle group

--intrcpt: intercept of that muscle group

** please see table 18 for additional abbreviations that were used.

LIST OF FIGURES

LIST OF TABLES

SIGNIFICANT FINDINGS

The major findings from the current study are presented in the following. The results from specific aims 1 and 2 indicate that with more months of job experience on inclined and/or elevated surfaces, subjects were able to more accurately perceive the angle presented. Also, younger workers and those who took more time answering were able to more accurately perceive the angle presented. This indicates that workers may be able to adapt their visual spatial perception (VSP) with work experience on inclined and/or elevated work surfaces. This also demonstrates that with age, VSP may become weakened. For the fatiguing effect, the half and full load significantly decreased the number of correct VSP responses. This experiment tested acute muscular fatigue. Future experiments may include mental fatigue and more chronic muscle fatigue. Fatigue, both physical and mental is often a problem in the workforce, especially at the end of a shift. By perceiving the angle correctly, the postural balance will be more stable since the person accurately perceives the visual cues available to orient him/herself. This study showed that experience, fatigue, age and response time was important for a worker to accurately perceive the visual-spatial environment. The significant findings from specific aims 3 to 7 dealt with effect of experience, task type, inclination, muscle fatigue and visual cue on objective and subjective measures of postural balance, postural muscle contraction patterns and eye movement patterns of industrial workers. The main effect of task type and inclination were found to be significantly affecting postural sway and postural stability. In other words, in comparison to the stationary task sway and stability variables increased for the reach task implying poorer postural balance. Similarly, with increasing inclination angle from 0 degrees to 26 degrees majority of the sway and stability variables increased implying poorer postural balance. The main effects of visual cue on the postural sway variables were found for only sway length for two models (25^{th} and 5^{th} percentile of EMG activity). For other three models (95^{th}, 75^{th} and 50^{th} percentile of EMG activity) the sway length was marginally (p-value range: (0.05 –0.1) influenced by visual cue. The analysis of postural stability indices revealed that increase in experience is associated with lesser amount of postural instability while performing task on inclined surfaces. Also the postural instability was highest for task performance on 26 degree inclined surface compared to both 0 and 14 degrees. The experience variables tended to be more highly related to the EMG outcomes, both as main effects and when interacted with the experimental conditions and muscle strength. In the vast majority of these models, greater experience or work activity predicted that the worker would experience lessened EMG activity. This is expected since increased EMG implies more muscle contraction, which in cumulative sense will bring about muscle fatigue. Therefore the results imply that experienced workers are using lesser amount of muscle activity to perform the task as compared to inexperienced worker. The fatigue factor did not show significant effect on postural sway. The months of work experience (exp_job) model showed experience as a predictor for RMS velocity of eye motion, weighted eye movement length, center fixation percentage, weighted cluster distance, sway area and sway excursion in the medio-lateral direction. For the eye movement variables, the subjects with more months of experience have larger RMS velocities and more fixations on the center cue, but shorter eye movement lengths and cluster distances. This indicates the more experienced subjects looked around less and fixated more on the center cue. The visual cue was a predictor of several eye movement outcome measures. For the eye motion area and cluster distance the visual cue decreased the value for all experience models implying that the subjects utilized the visual cue when it was present. For the fixations, the value was higher when the visual cue was present for the center

and directly around the center cue (0-5") and lower for the fixations further away from the cue, which is expected. This would indicate the subjects looked at or around the center cue when the visual cue was present and tended to look around more when the cue was not present. The visual cue was also significant for the sway length with the length decreasing when the visual cue was present implying improved postural balance.

The main effect of task type and inclination produced significant effects on PSOF. The reach task produced a lower PSOF score than stationary task implying that workers perceived the reach task to be less threatening to their postural stability. This unexpected finding implies that since during reach task the workers were conducting a voluntary motion their perceived postural stability was less threatening than that for the stationary task, which produced more of a non-voluntary body sway. This subjective response of postural stability to task type is opposite to the objective measure of postural stability. In other words the reach task always produced a higher response in objective measure of postural sway (measured by SA, SL and excursion values in the ML and AP directions) than that for the stationary task implying an increased postural instability. Therefore, there is a mismatch between subjective and objective responses of postural stability for the performance of two tasks. This type of mismatch may prove to be a reason for safety hazard due to potential fall or near fall event to occur. The inclination levels 0 degrees to 14 to 26 degrees produced a monotonically increasing scores of PSOF implying that workers perceived their postural stability to be increasingly threatened as the inclination increased.

ABSTRACT

This study provides an experimental design for investigating the main effects and interaction between fall risk factors associated with task performance on inclined surface on workers' postural balance, postural muscle contraction patterns and eye movement patterns. The risk factors studied were standing surface inclination, job-task type, and experience in working on inclined/elevated surfaces, physical fatigue, and lack of visual cue in the environment. In this study, postural instability and propensity of loss of balance due to fall risk factors were evaluated for 82 industrial workers' performance (20 to 58 years of age) on test conditions, which represent combinations of these risk factors. This study addressed the following questions: (a) How do work surface inclination and muscle fatigue affect postural balance and postural muscle contraction patterns and eye movement patterns? (b) Do workers with experience in working on inclined surface have better visual spatial perception than those with no experience and (c) Does an experienced worker utilize his/her visual environment differently than the inexperienced worker in maintaining better postural balance during task performance on inclined surface? Results obtained from this study with industrial worker subjects now provide the basis for future prospective studies using a larger sample to determine the impact of training programs for improving postural balance of inexperienced workers working on inclined surfaces. The results obtained from this study will now help enhance our existing statistical model showing the relationship between postural stability and propensity of loss of balance and the independent variables characterizing the experience, muscle fatigue, job-task type, visual cue and personal risk factors. The significant findings from this study are given in the previous Section.

A. SPECIFIC AIMS

In the following, a brief summary of specific aims of the project as funded is presented.

1. To determine the effect of workload on visual spatial perception (the ability to detect correctly vertical and horizontal cues) in "experienced" and "inexperienced" workers. (Phase 1)

2. To determine the effect of workload and standing on an inclined surface (modified proprioception) on visual spatial perception ability in "experienced" and "inexperienced" workers. (Phase 1)

3. To determine the effect of workload and environmental lighting on the ability to maintain "safe" upright postural balance in "experienced" and "inexperienced" workers while performing simulated industrial tasks on inclined surfaces. (Phase 2)

4. To determine the effect of workload and environmental lighting on characteristics of visual information (fixation time, frequency of fixation, time history fixation and speed of eye tracking) used by "experienced" and "inexperienced" workers while performing simulated industrial tasks on inclined surfaces. (Phase 2)

5. To determine the effect of workload and environmental lighting on the muscular contraction patterns of postural muscle groups in "experienced" and "inexperienced" workers while performing simulated industrial tasks on inclined surfaces. (Phase 3)

6. To determine the effect of strategically placed visual cues in minimizing workload and/or environmental lighting induced detrimental effect on the ability to maintain "safe" upright postural balance while performing simulated industrial tasks on inclined surfaces. (Phase 3)

7. To determine the effect of strategically placed visual cues in modifying workload and/or environmental lighting induced effects on the characteristics of visual information (fixation time, frequency of fixation, time history fixation and speed of eve tracking) and the muscular contraction patterns needed to maintain "safe" upright postural balance while performing simulated industrial tasks on inclined surfaces. (Phase 3)

B. BACKGROUND AND SIGNIFICANCE

Workers (construction workers, roofers, miners & drillers and operating engineers, etc.) who labor on elevated and/or **inclined surfaces** have relatively higher incidences of deaths/injuries due to falls than other work related causes [1-2]. As per 1980-89 survey by NIOSH, the construction industry had the highest numbers (6.56 out of 100,000 workers) of fall related fatalities followed by the mining industry (1.89/100,000)[3]. In another analysis of data from NIOSH's database of Fatal Accident Circumstances and Epidemiology (FACE) for 1987-1989, it was found that fatal falls have occurred from heights as low as three feet.[4]

As per the 1988 Bureau of Labor Statistics (BLS) data, fall was the third leading cause of work-related injuries.[5] The construction industry has the highest percentage (22%) of fall-related injuries, followed by the service, transportation, public utilities, trade, and wholesale/retail

industries.[5] As per 1990 Ohio Injury Statistics from the Bureau of Workers' Compensation (BWC), 3322 injuries out of 10,120 were due to falls from a different level.[6] The severity of injuries due to fall from an elevation is significantly higher than that of fall from the same level. Falls have been found to be a significant contributor in causing lumbar spine injury, fracture of bones, and disability.[7,8] In 1990, the Ohio BWC reported average days lost due to fall from elevation was the highest at 25.3 days compared to 18.9 days and 19 days due to fall at the same level and overexertion, respectively.[6] According to compensation data covering 91,953 construction accidents in New York from 1980-1988, falls had cost the second largest amount ($231,889,484).[9]

In an analysis of accident profiles among New York industries, Cohen[10] found that falls were attributable to a combination of **surface conditions and poor lighting**. They also reported that 66% of these accidents occurred indoors where lighting conditions might be less than optimal, as in the case of new construction.

The reasons for fall incidences are many, e.g., accidental tripping, lighting, fatigue, health status, task characteristics, etc. A majority of falls and near falls can be analyzed as an incident, which started with loss of balance, experienced by the worker. There are several risk factors at the workplace, which can detrimentally affect workers' ability to maintain upright balance. In a recently completed study in our laboratory with 52 industrial workers, we found that environmental lighting, task type, peripheral vision, physical workload and standing surface firmness detrimentally affected their postural balance while performing industrial tasks on a level surface (Final Performance Report: R01-OH-02794). Since the maintenance of upright balance depends upon afferents from three physiological pathways (vision, proprioception and the vestibular system) it is necessary that all three pathways have congruent information regarding the somatosensory and gravitational reference present in the worker's surrounding. If for example, proprioception and/or vestibular information is compromised, then excessive demand will be placed on the visual system for the maintenance of "safe" upright balance. This scenario is not uncommon in a workplace. For example, a construction worker in a poorly lit environment (during early morning or late evening or while in a poorly lit building) performing some dynamic task (requiring him/her to dynamically move his torso/head i.e. to bend down or turn/twist) while standing on a wooden plank placed on an uneven (or inclined) and soft surface will detrimentally modify his/her proprioception information and place an undue challenge to his/her visual and vestibular system. Under these circumstances, availability of "correct" visual cues will be compromised due to "poor" environmental lighting. This may cause a significant error in worker's visual spatial perception. Furthermore, previous researchers have shown that physical fatigue can greatly impair younger (mean age 27 " 11 years; range 15 to 41 years of age) subject's ability to correctly perceive visual information [11]. In another study, it was shown that older adults have significantly larger degree of error in their visual spatial perception [12]. These studies however, did not address the issue of age related and fatigue related visual perception modifications on the ability to maintain upright balance. Some of these issues were investigated in this study.

A survey by the Bureau of Labor Statistics found that being tired or fatigued contributes to the occurrence of accidental falls. Previous studies in our laboratory[13] have found detrimental effect of workloads of 85 watts or higher on an individual's ability to maintain upright balance on a level surface. These effects were further enhanced when cardiopulmonary loadings were increased during respirator wear. The results from this study implicated workload induced modification of the functional aspects of the proprioception and/or vestibular system as the contributing factor for observed "impairment" to the postural balance. Under these circumstances, when the functional abilities of proprioception/vestibular systems are being compromised due to physical fatigue, it is reasonable to expect excessive "burden" to lie on the

vision system for the maintenance of upright balance. Therefore, it is important to determine whether fatigue resulting from physical activity affects the visual perception ability and its influence to maintain upright balance, and whether the additional physiological strain and/or psychological strain imposed by working on an inclined surface with poor lighting creates an increased susceptibility to loss of balance, resulting in a potential fall. The contribution of visual input becomes even more important to a continually aging workforce[14]. The aging process significantly affects a person's ability to maintain upright balance. The results from the current study provide some insights into above matters.

B.1. RELEVANCE AND SIGNIFICANCE TO WORKERS' HEALTH AND SAFETY

There exist many challenging workplace environments such as those in the construction industry, where aging workers' visual as well as vestibular systems are placed in a compromising situation because of existing workplace risk factors. These include environmental lighting, standing surface inclination and compliance, physical workload and task type, all of which might detrimentally jeopardize his/her ability to maintain a "safe" upright balance, resulting in a near fall or actual fall incidence. Reasons for such incidences of falls or near falls are many. Some investigators have attributed some of these falls to lack of new worker training and unfamiliarity of the workplace. The role of training in tasks being performed on inclined and/or elevated surfaces requires careful attention, as the consequences of falls are deadly and immediate. Based upon physiological and biomechanical rationale, it can be assumed that one of the important first events which may eventually result in a fall or near fall is lack of ability to maintain "safe" upright postural balance due to various environmental and job-task risk factors while performing tasks on inclined and/or elevated surfaces. The need for improved upright balance under these circumstances can be met by proper training of postural muscles. In the sports industries and with elderly subjects it is well established that the ability to improve upright balance is possible through conditioning of the postural muscles

In spite of high rates of worker injuries and fatalities, (i.e., workers in trades such as roofing) who work on inclined and/or elevated surfaces, many continue to work in this trade. Many issues contribute to the decision to stay in such a demanding and "risky" occupation. The present study deals with the assumption that a worker (e.g. roofer) who has "survived" at least three years of physically demanding task and the danger of working on inclined and/or elevated surfaces would have adapted his/her neuromuscular and other physiological system to meet the demand of maintaining "safe" upright postural balance while working on inclined and/or elevated surfaces. As no quantitative data regarding the characteristics of postural balance of "experienced" workers exists, the proposed study is designed to collect such data. Availability of such data will allow us to 1) develop planned training programs for new workers who have to perform physically demanding tasks on inclined/elevated surfaces 2) to determine the need of visual cues to minimize excessive postural muscle fatigue and maintain a "safe" upright balance while working on an inclined and/or elevated surface. Before initiating plans to develop training programs for improving postural balance, we need to first quantitate the detrimental effects of various environmental (lighting) and job-task (physically demanding workloads and tasks) risk factors on workers' ability to maintain upright balance while working on an inclined surface. The need to maintain a "safe" upright balance for construction workers (such as roofers in precarious conditions on inclined/elevated surfaces) is equally important and compels our attention toward

correcting this problem.

C. METHODS

For this report, the experiment 1 and 2 in the grant proposal is Phase 1, experiment 3 is Phase 2 and experiment 4 is Phase 3. The protocol for this study was reviewed and approved by the University of Cincinnati's Institutional Review Board. All subjects read the consent form (see Appendix A) and signed it before beginning the experiment.

C.1. Worker-Subjects

A total of 82 subjects were recruited for this study, which was carried out in three phases. Phases 1, 2 and 3 used 60, 50 and 48 subjects, respectively. The subjects were recruited from Unions, with whom we have established contact, which represent a variety of trades. These included service trades such as roofers, maintenance, janitorial, commercial food service workers, construction workers and plumbers/pipe fitters.

Contact with potential subjects was made via fliers and via communication with subjects from previous studies performed in our laboratory. The fliers were either posted in the Union Hall, sent as direct mailings, or through informational meetings with groups. Once contact was established and potential subjects had volunteered, they were first screened using a telephone interview and preliminary questionnaire (see Appendices B and C) to determine both health and work status and occupational exposures to chemicals known to produce health and postural balance effects.

Upon satisfactorily completing the preliminary questionnaire phase of screening, potential subjects were then examined medically by a physician, who made the final determination as to whether the individual was in fact suitable for inclusion in the study. The medical screening included cardiopulmonary, neurological, visual, proprioceptive, vestibular, and musculoskeletal checks, and the subject completed a health history check-up. Exclusion criteria included daily requirements of prescription medication, current smoking and alcohol habits, history of dizziness, tremor, alcoholism, vestibular disorders, neurological disorders, cardiopulmonary disorders, diabetic symptoms, chronic or acute low-back or knee pain, aphasia, brain damage, vision related diseases (such as glaucoma, etc) and those unable to perform our assigned task due to non-specific visual impairment. Each subject was also screened for visual performance including acuity, stereo depth perception, color discrimination, vertical and lateral phoria and peripheral field of vision. If the physician deemed it necessary to exclude individuals from participation, they were referred to their primary care physician for follow-up. Once an individual was included as a study participant, they were given a set of guidelines to clarify and reinforce the study protocol requirements.

The workers were divided into two groups, experienced and in-experienced. The experienced subjects were experienced in working on inclined and/or elevated surfaces such as roofers, ironworkers, glazers, painters, etc. The in-experienced workers had no experience working on inclined and/or elevated surfaces. The criteria for placing a worker in the inexperienced category was a worker with less than 1-year experience of working on inclined and/or elevated surfaces. Workers with 1 to <3 years of experience were not included in the study. Workers with 3 years or more of continuous experience on inclined/elevated surfaces were considered experienced. A work history was completed in the telephone interview (see Appendix B) to determine this

criteria and to obtain the months of experience and average number of hours per week spent working on an inclined surface, which were also used as continuous variables in the final analysis.

Due to the number of visits to the laboratory required by subjects, every effort was made to schedule appointments with consideration given to individual work schedules. Recruitment was therefore conducted in an ongoing fashion to insure an evenly distributed workload and be able to accommodate the workers' schedules. This method of recruitment allowed the subjects to be actively involved over a shorter period of time, thereby increasing the participation rate and decreasing the potential attrition rate due to various reasons including loss of interest, conflict with workers' schedules and changes in lifestyle which might affect their health status. To assess the time of day and the amount of work the subject completed (at his/her place of employment) before arriving at our laboratory on the testing day, the subject's recent work history and pain/discomfort related to the twelve hours prior to testing was collected (see Appendix D). This data was used in the statistical analysis.

C.2. Risk Factors/Treatment Conditions (Independent Variables)

C.2.a. Phase 1 (specific aims # 1 and 2)

The following two independent variables were used in Phase 1 of this study.

C.2.a.1. Inclined Surface: Based on our previous study of inclination and elevation three levels of inclination were chosen, 0°, 14° and 26°(Final Performance Report: Fall Potential of Work on Elevated and Inclined Surfaces. R01-OH03107-03). A majority of constructions (both residential and commercial) use the above-mentioned roof inclination angles. Three specially designed inclined surfaces were attached to the force plate to obtain the desired values of inclinations (see figure 1).

Figure 1. The 26° inclination placed on the force platform.

C.2.a.2. Workload: Three levels of workload were used, none (0%), half (50%) and full (100%) load. The workload consisted of fatiguing the subject's postural muscles in his/her legs. The subject maintained a semi-squat position until he/she could not maintain the posture any longer. During the squat position, the subject was required to perform a manipulation task on a Minnesota Activity Board placed on a table at the subject's knee height and at a distance of the subject's forward functional reach. The manipulation task performed by the subject involved turning a small pawn with both hands on the Minnesota Activity Board. The time that the subject could

Figure 2. The semi-squat position maintained to achieve a workload in this study.

voluntarily maintain the semi-squat position, which was until they experienced unbearable discomfort in their leg muscles, was recorded as the 100% workload time[15]. The recorded maximum time was then divided by two to obtain the 50% workload. For the 0% workload, the subject did not squat. See figure 2 for a picture of the workload task.

C.2.b. Phase 2 (specific aims # 3 and 4)

The same two independent variables from Phase 1 were used in Phase 2 along with the following variable. All testing was performed in poor lighting conditions (<1 foot-candle) except for the baseline test. The baseline test was the stationary task, 0° incline, no load and "good" light.

Figure 3. The position of the reach task as the subject reaches for the weight.

C.2.b.1. Postural Stability Tasks: Two tasks were completed by the subject. One was a stationary task where the subject stood erect on the force platform for 30 seconds with his/her hands on her hips. The second was a reach task where the subject (i) Stood erect on the platform for 7 s, (ii) reached forward to pick up a weight attached to a 2x4x24 in^3 wood (cumulative weight of 5.2 lbs), brought it close to his/her abdomen, and replaced it on the shelf, (iii) repeated step (ii) for 4 cycles, (iv) reassumed the erect position for the remaining time. The shelf was placed at the waist height and at a functional reach away from the subject as shown in figure 3.

C.2.c. Phase 3 (specific aims # 4,5,6 and 7)

The same independent variables from Phases 1 and 2 were used in Phase 3 along with the following variable.

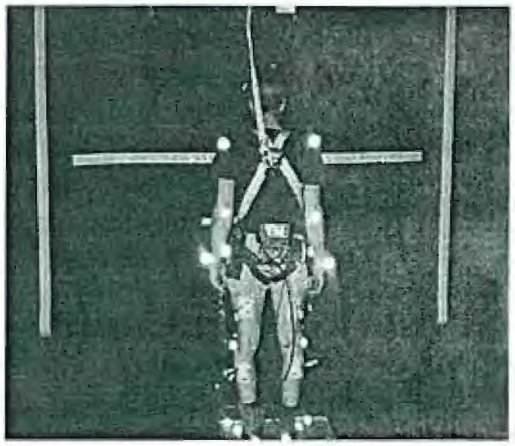


Figure 4. Visual cue placement for the "H" cue.

C.2.c.1. Visual Cue: Two visual cue conditions were used in this phase of the study, no cue and an "H" cue. The "H" cue was one horizontal cue with a vertical cue at either side of the horizontal cue (see figure 4). These cues were made from self-illuminating strips that were visible when the lighting was poor (< 1 foot-candles). To determine the position of the cue, a previous study (Final Performance Report: Fall Potential of Work on Elevated and Inclined Surfaces. R01-OH03107-03) and Phase 2 eye movement data was used. See the results section for details.

C.3. Study Facility for Phases 1,2 and 3

C.3.a. Specialized Enclosure Unit: The unit consists of three modular framework structures, made of lightweight aluminum that can be fitted with fabric panels. Figure 5 provides a schematic representation of the enclosure system. These enclosure walls (panels) use a flat black

felt-type fabric that forms a uniform viewing surface offering minimal visual cues. The aluminum panel framework pieces are interconnected with removable screw-knobs. The cloth panels, made of feltwork fabric on fire-resistant plastic sheath are lined with magnetic strips. Matching strips are found on the framework pieces. A rigid roof structure, made of the similar material as the walls of the enclosure, was hung from the top to add uniformity to the appearance of the enclosure.

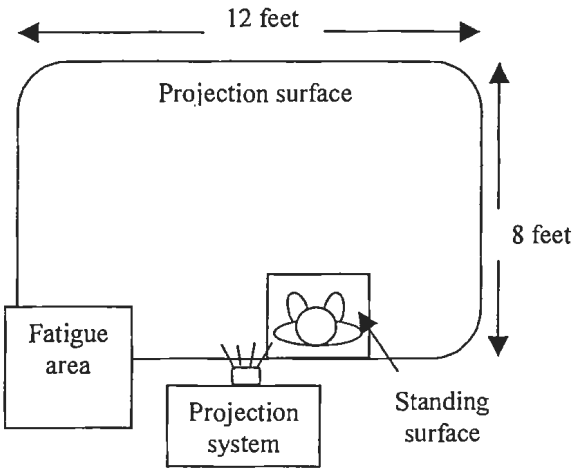


Figure 5. Lab set-up for Phase 1.

The roof of the enclosure extends up to and above the subject's head. The floor of the enclosure was covered with a low-pile black carpet to minimize further visual cues. This facility includes a specially designed overhead single-point safety harness hookup. This system accommodates a hook that allows the whole body safety harness to be attached to it while the subject stands on the inclined surface performing the assigned study protocol. The Phase 1 lab schematic is shown in figure 5. A force platform (Advanced Mechanical Technologies Inc. (AMTI) model OR6-6-1000, serial # 3217) was used for Phases 2 and 3 and is shown in the lab set up in figure 6.

C.3.b. Camera set-up for Phases 2 and 3: The camera set-up for Phases 2 and 3 included five cameras and uses a three-dimensional *direct linear transformation* (DLT) analysis for more accurate calculation of the marker movement and the movement of the center of gravity (CG). Figure 6 shows the layout of the five cameras used in Phase 2 and 3 of this study. Specifications for the cameras: Camera #1: Burle 60Hz (model TC351A, serial #917581); Camera #2: Pulnix 60 Hz (serial # 001166) Camera #3: Burle 60 Hz (model TC351A, serial # 909165); Camera #4: Burle 60 Hz (model TC351A, serial # 909047); Camera #5: Pulnix 60 Hz (serial # 001161).

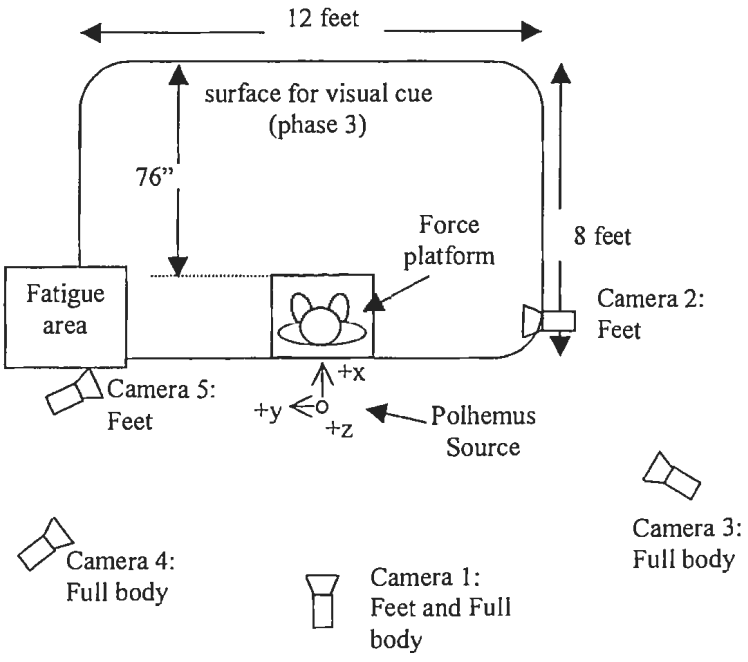


Figure 6. Lab and camera set-up for Phase 2 & 3.

C.3.c. The Estimated Maximum Displacement of Center of Gravity Measurement (EMAX) Set-up:

The test facility for the EMAX test consisted of a force platform (AMTI model OR6-5-1000, serial # 3352) flush with the ground, a foam board (32" x 40") installed in front of force platform as a reference for the subject to "push" against. Four cameras were used for this test. The camera placement and lab set up is shown in figure 7. The camera specifications are: Camera 1: Burle 60Hz (model TC351A, serial # 925621); Camera 2: Burle 60Hz (model TC351A, serial # 917581); Camera 3: Burle 60Hz (model TC351A, serial # 909165); Camera 4: Burle 60Hz (model TC351A, serial # 909047). The EMAX task is explained in detail in Section C.6.c.1.

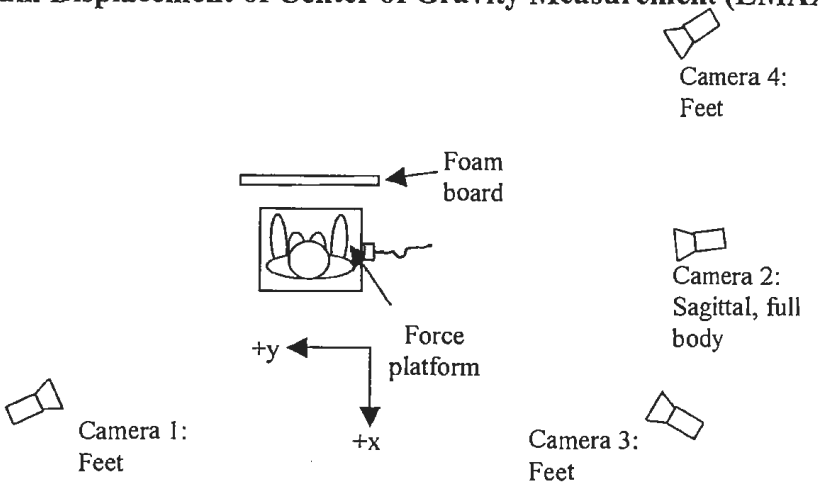


Figure 7. Lab set-up for EMAX.

C.3.d. Voluntary Maximum Contraction (VMAX) Lab Set-up: A plinth was set up for the subject to sit in various postures on to measure the various muscle groups' voluntary maximum contraction. Two columns of angle irons (for the right and left side of the body) were bolted to the wall at one end of the plinth to attach the load cell (Jackson Evaluation System, model 32528; serial 280256) and cable leading to the subject's ankle or foot perpendicular to the wall. The load cell height was adjustable up and down the angle irons. This ensured the load cell was set to measure the perpendicular force exerted by the muscle group (i.e. the subject was pulling or pushing perpendicular from the wall). A figure showing this set up is shown in Appendix E.

C.3.e. Specially-designed inclined surface: Specially-designed structures were constructed to provide all three inclinations (0 °, 14°, and 26°). The structures were made of cast iron and sand-blasted to remove any glare it may produce when videotaped and to increase the friction between the subjects' shoe sole and the standing surface for a safer grip while standing. A flat piece with connectors on each corner was placed directly on top of the force platform and the incline structure was then attached to this flat piece (see figure 1).

C.4. Instrumentation and Measurements

C.4.a. Kinetic measurements

The kinetic measurements, which included the forces and moments exerted on the force platform, were collected using two piezoresistive force platforms (AMTI, Watertown, MA) capable of measuring forces and moments in the three orthogonal directions. One force platform was used for the EMAX test (Model OR6-5-1000, serial # 3352) and the other for Phase 2 and 3 (Model OR6-6-1000, serial # 3217). The details regarding the accuracy of the force plate are available in Bhattacharya[16] . Each force platform was placed flush with the floor. The signals

from the plate were fed into an amplifier (AMTI, model SGA6). The amplifier was set with a gain of 4000 and a low-pass filter of 10.5 Hz for balance testing and 1050 Hz for the EMAX test (see Appendix F). The signals coming out of the amplifier were then delivered to an IBM compatible, Pentium computer using A/D board and Peak™ Performance Software (Peak Performance Technologies Inc., Englewood, CO) for data collection. The data collection frequency was set at 60 Hz and a duration of 30 seconds (1800 data points). Collected data was further processed to calculate the movement patterns of the body's CP which were then used to determine the variables of postural sway and postural instability.

C.4.b. Mathematical and experimental computation for the determination of the center of pressure (CP) using the force platform and the specially designed inclined surface

The footprints, in conjunction with the CP trace, were used in the calculation of the indices of propensity towards Loss Of Balance (LOB). Since, the LOB indices are based on the physics of upright stability, it depends on the basal support area available to the subject. In the case of the inclined surface shown in figure 8, the basal support area is given by the cosine projection of the subject's footprints on the horizontal plane (where forceplate was located).

Mathematically,

(Modified basal support area) = (Support area on the inclined surface) x cos θ

where, θ is the angle of the incline to the horizontal.

Hence, the LOB indices based on the CP data was evaluated by using the modified basal support area described by the above formulation.

Placement of the inclined and/or elevated surface displaces the actual point of application of the force from the top surface of the force platform. Thus, it requires special consideration when determining the value of the distance c of the point of application of the force from the electrical center of the platform. As shown in figure 8, the point of application of force is at a distance of C_s from the surface of the plate and at a distance of c ($c = C_s + C_e$) from the electrical center of the plate. The equation for the calculation of the CP based on the forces and moments measured using the force platform may be given by [16]:

$$x_p = \frac{(\vec{M}_z \vec{F}_y - \vec{M}_y \vec{F}_z)}{|\vec{F}^2|} - \frac{(\vec{F}_x^2 \vec{M}_y - \vec{F}_x \vec{F}_y \vec{M}_x)}{\vec{F}_z |\vec{F}^2|} - c \frac{\vec{F}_x}{\vec{F}_z}$$

$$y_p = \frac{(\vec{M}_x \vec{F}_z - \vec{M}_z \vec{F}_x)}{|\vec{F}^2|} - \frac{(\vec{F}_x \vec{F}_y \vec{M}_y - \vec{F}_y^2 \vec{M}_x)}{\vec{F}_z |\vec{F}^2|} - c \frac{\vec{F}_y}{\vec{F}_z} \qquad \text{Eq. (1)}$$

Here, c is calculated by adding the z component of distances C_e (the electronic center of the force platform) and C_s(the center of the surface on the force platform) as shown in the figure 8. Experiments were performed by placing a heavy cylindrical metal bar of known weight at pre-determined locations on the inclined surface. Our previous study (Final Performance Report:

Fall Potential of Work on Elevated and Inclined Surfaces. R01-OH03107-03) gives the details of the experiment to validate the use of the equation (1) with modified c value. As concluded in our previous study, the range of error of measurement was 1-4% and provide a good approximation of the movement of CP as calculated from the force platform. The movement of CP in terms of the center of the plate are combined with the projected footprints (to the horizontal plane at the force plate) of the subject to compute the indices of postural stability.

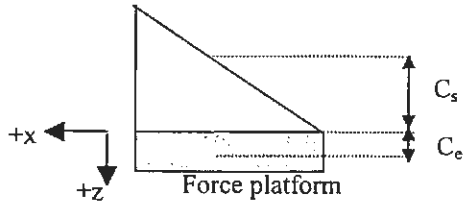


Figure 8. The distance of the force applied on the force platform

C.4.c. Kinematic Measurements

The kinematic measurements, which included linear and angular displacement, velocity, and acceleration, were collected using a videographic motion measurement system (Peak™ Performance Technologies Inc., Englewood, CO). An Infrared (IR) light source of 250 watts capacity was installed next to each camera in order to be able to record the marker movement in both good and poor lighting conditions. The video data was collected at a sampling rate of 60 Hz.

The Peak Performance system was used for the digitization of three-dimensional spatial movement of the markers. For Phase 3, Peak Motus Video digitizing software was used. Calibration of each test session was performed to ensure the accuracy of the digitization. After digitizing the video pictures, the whole body CG movement was determined. The data from the force plate and videographic system were synchronized with the help of an event synchronization system. The origin of the coordinate system was defined as the upper left corner of the force platform. After the data was digitized, the coordinates were translated in the Index of Proximity to Stability Boundary (IPSB) software. The coordinate system for the Peak, IPSB and force plate data are shown in Figure 9.

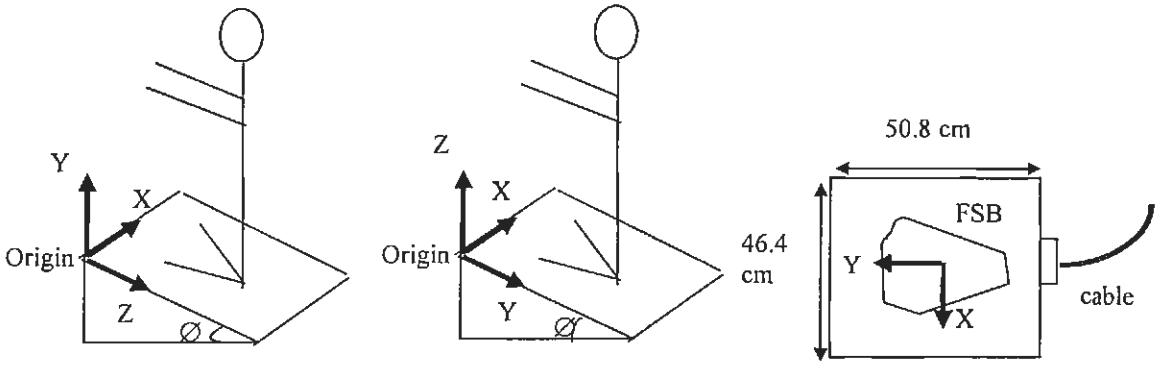


Figure 9. a. Peak coordinate system b. IPSB coordinate system c. Force platform coordinate system

C.4.d. EMG Measurements

An 8 channel Paromed data logger (PDL) telemetric EMG recorder (Paromed Inc, Germany) was used to measure the EMG signal from 8 muscle groups of the lower limbs. The input impedance of the PDL was 100 G Ohm with a gain factor of 100 for pre-amplification and a lower frequency cut-off at 10 Hz in the probe. The common mode rejection ratio (CMRR) for the PDL

was 100db. A PCMCIA card was used for digital data storage in the PDL during data collection. Data Logger Software or DLS (Paromed Inc., Germany) was used to configure the PCMCIA card for data collection time (30 seconds for postural sway tests, 12 seconds for Vmax trials, 10 seconds for resting EMG trials). A data sampling rate at 1000 Hz and a gain factor of 8 for all channels were used. Data collection was triggered by a remote control device with a transmitting frequency of 72 MHz. The kinetic and EMG data collections were triggered simultaneously through an Event Synchronization Unit (ESU) by the tester using a remote control device. Placement of electrodes for this study can be seen in Appendix G.

C.4.e. Eye Movement Measurements

Eye movement data was collected with the ISCAN Eye/Head Movement Monitoring System (ISCAN Inc., Burlington, MA). This system consists of a computer-based workstation, remote headgear, Polhemus magnetic reference source and subject's calibration monitor. The precision, accuracy and reliability were tested in the laboratory setting used in this experiment and are described in the following sections. To collect plane intersection data, planes were defined in the viewing area of the subject. Up to 25 planes can be defined with the first plane being the subject's calibration monitor, which was used for calibration of the system. We used 12 planes in our experiments because the data collection frequency was decreased if more than 12 planes were defined. Eye and Head movement data were collected at 60Hz in these experiments. The upper left, upper right, lower left and lower right coordinates were defined for each plane (see Appendix H). These coordinates were the physical distance from the Polhemus magnetic reference source. This reference source was suspended from the ceiling directly behind and above the subject for Phases 2 and 3 and was 84" from the ground and approximately 22" behind the subject (see figure 6 for Polhemus location). It was possible to raise and lower the reference source as needed, but was not adjusted throughout the study period. Plane 1 was the subject's calibration monitor. It was required to be directly in front of the subject and was hidden when not in use by the front panel. Plane 6 was the area immediately surrounding plane 1. Since the ISCAN software "looks" for a plane intersection beginning with the first plane, all data points on the area of the television (even though it is covered during a trial) were described as in plane 1. Each of the defined planes was a rectangle of 40" by 36" that divided the front wall (120" by 108") into nine equal sections. These planes were defined in the ISCAN system as planes 2 through 10 since the calibration monitor was defined as plane 1. Two additional planes were

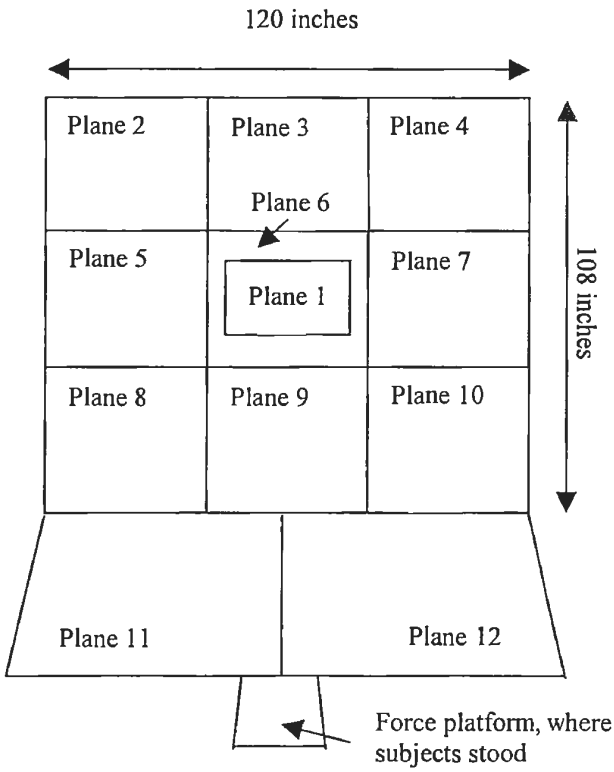


Figure 10. Schematic of plane definitions for ISCAN.

defined on the floor of the testing chamber and divided the floor equally in half. Figure 10 shows the planes as defined in Phase 2 and 3. A plane 0 is recorded by ISCAN when the subject looks off of the area defined by the planes. Figure 11 shows the calibration monitor installed in the front wall of testing chamber.

C.4.e.1. ISCAN System Calibration:

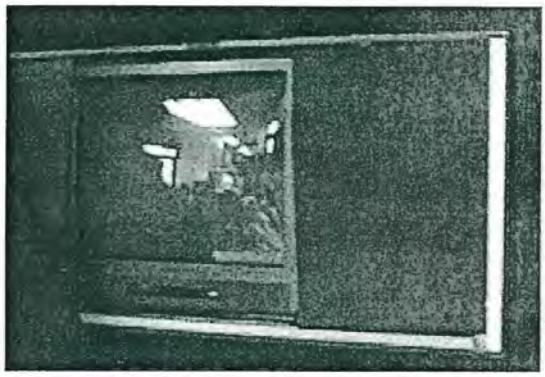


figure 11. Subject's calibration monitor for ISCAN

To calibrate the system, the subject stands with the headpiece on his/her head on the force platform. The subject puts on a modified swim cap before placing the ISCAN headpiece on (see figure 12). This reduced the chance of the headpiece slipping after calibration. The subject looks comfortably forward towards the calibration monitor (plane 1 in figure 10). The monitor displayed videotape that had the locations for the calibration in blue dots and four numbered reference points (1-4) for checking the calibration. The numbers were 1.5" squares, which ensured the calibration was as accurate as demonstrated in the accuracy testing of the system for this plane (Plane 1). The blue dots are at a certain visual angle, 4.25°, that is set in the software. A schematic of this display is shown in figure 13. The subject was then "boresighted" which engages the head monitoring by the Polhemus system. The subject then saw flashing white squares that move with his/her head. The subject was instructed to keep his/her head still so that the white squares stay on the blue dots on the screen. The subject then looked at each dot as instructed by the ISCAN operator: center, left, right, top and bottom. As the subject looked at a location, it is entered into the computer. To check the accuracy of the calibration, the subject was asked to look at the numbers 1 to 4 and the ISCAN operator could check the line of sight and ensure it was on the correct number. If the calibration was poor, i.e. the ISCAN system showed the subject looking around the number instead of on it, it was repeated. Instructions for operating the ISCAN system can be seen in Appendix I.

figure 12. ISCAN Head piece

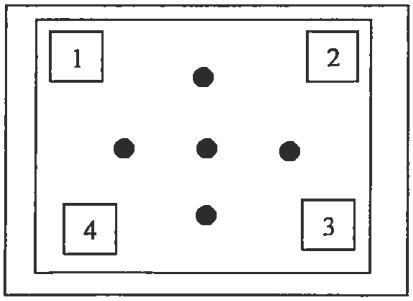


Figure 13. ISCAN calibration display

C.4.e.2. Reliability Testing:

During the reliability testing, the subject was instructed to stand erect wearing the eye-tracking headpiece in front of the 9 defined targets, planes 2 through 10, at a distance of 86 inches (see figure 10 for the planes). The subject was instructed to look at the center of each target 10

seconds in a series, starting with target 2 and ending with target 10. The sampling rate of intersection points was 60 Hz, so approximately 600 intersection points were recorded when a subject was looking at each of the targets. The expected percentage of intersection data points recorded would be 100%. However, this would be reduced due to the combined effects of blinking, calibration error and instrument accuracy (specified by manufacturer as ±1° visual angle in the 30° range of viewing).

The reliability test was comprised of testing variations of intersection points recorded in 9 defined targets between-subject and those between-operator. Three operators and two subjects participated in this test. Operators A and B tested each other and Operator C tested both of them. No fatiguing task was completed for this test. The results are shown in Table 1. The percentages of intersection points recorded for all targets are consistent between operator B and C, same as those for target 2 to 4, 7, 9 and 10 between operator A and C. However, for target 5, 6 and 8 there are considerable differences of intersection points recorded between operator A and C, which indicates that variations of intersection points recorded between-operator are somewhat different for certain targets. It can be explained due to that the eye-angle calibration done by operator C was not good for target 5, 6 and 8 or due to that the subject blinked too much while looking at those targets since blinking interferes with the intersection points to be recorded.

Table 1. Percentage of plane intersection point recorded in the target planes.

	Subject	Operator A	Operator B	Operator C
Target 2	A		98.15	97.35
	B	97.46		97.68
Target 3	A		97.99	97.26
	B	100		100
Target 4	A		97.85	97.52
	B	100		100
Target 5	A		97.97	99.02
	B	92.48		40.86
Target 6	A		98.52	98.55
	B	97.5		58.21
Target 7	A		99.0	100
	B	100		98.36
Target 8	A		100	97.91
	B	87.35		70.49
Target 9	A		97.1	98.26
	B	97.32		100
Target 10	A		97.18	97.78
	B	99.39		97.97

C.4.e.3. Accuracy Testing: To determine the accuracy and precision of the eye tracking system, subjects focused on the center of a specific plane and from the results, the center of the data points collected and the actual center of the plane were compared. Planes 1, 3, 5, 7, 9, 10, 11, and 12 were used as targets (see figure 10). The eye/head tracking system was calibrated and data was collected for 5 seconds for each target plane. The subject was asked to focus directly on a dot that was placed in the center of the designated plane without blinking during the test.

This was repeated seven times with the same calibration for a single plane. The subject was allowed to rest and then this was repeated for each target plane. The bias, direction of bias, 95th percentile area and angle of visual "focus" were calculated as shown in figure 14. Results from the accuracy test are shown in Table 2.

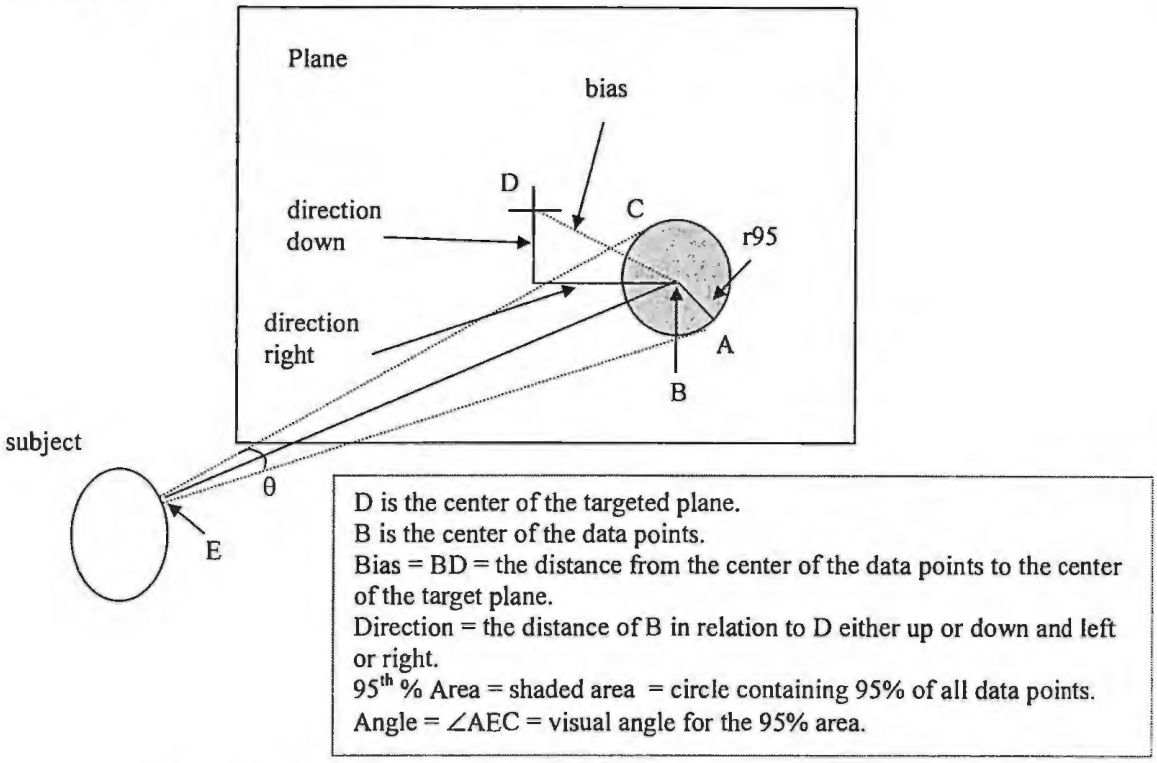


Figure 14. Accuracy and Precision variables calculated for the ISCAN system.

Table 2. Results of accuracy and precision testing of the ISCAN system.

Plane	Subject	Bias (inches)	Direction (inches)	95th % Area (inches ^{2})	Angle (°)
1	A	0.956	Down 0.26, Right 0.92	1.453	0.961
	B	0.829	Up 0.58, Right 0.47	1.858	1.070
3	A	0.824	Down 0.23, Right 0.69	4.301	1.479
	B	1.539	Up 0.42, Right 1.35	2.021	1.022
5	A	1.763	Down 1.53, Right 0.20	2.980	1.261
	B	1.416	Down 0.46, Left 0.55	4.155	1.436
7	A	4.894	Up 1.71, Right 4.57	3.437	1.292
	B	4.685	Up 3.56, Right 2.94	2.794	1.163
9	A	3.239	Up 2.98, Right 0.79	1.275	0.961
	B	4.158	Up 3.87, Right 1.21	3.275	1.264
11	A	23.224	Forward 19.48, Left 12.53	8.470	2.097
	B	28.344	Forward 26.33, Left 10.31	3.167	1.236
12	A	21.509	Forward 9.18, Right 19.36	2.596	1.371
	B	33.946	Forward 22.10, Right 25.77	5.495	1.771

C.4.e.4. ISCAN Reliability with Fatigue Pilot test: The following pilot test was composed of three trials including none, half and full load on one subject. Two operators, who ran the ISCAN

system, repeated this pilot test on one subject. The ISCAN system was calibrated on the subject, the subject completed the fatiguing task, then the subject stood on the force platform and completed the reliability test as described above in the ISCAN reliability test. The results are shown in Table 3. There are slight differences of intersection points recorded with and without maximum fatigue and with half fatigue.

Table 3. Percentage of plane intersection points recorded in the targets with no, half and full fatigue with one subject and two operators.

	Operator	No Fatigue	Half Fatigue	Full Fatigue
Target 2	A	96.92	74.71	92.72
	B	93.82	81.89	97.18
Target 3	A	96.38	85.83	92.68
	B	98.51	82.53	94.97
Target 4	A	98.49	90.85	98.11
	B	93.16	93.68	87.5
Target 5	A	98.35	93.55	95.27
	B	96.91	44.06	88.13
Target 6	A	96.54	71.92	96.57
	B	98.25	94.03	91.42
Target 7	A	100	78.14	93.9
	B	97.71	92.83	95.78
Target 8	A	97.1	93.34	89.71
	B	96.61	89.1	97.02
Target 9	A	100	93.3	94.74
	B	98.4	94.18	97.29
Target 10	A	100	95.27	94.41
	B	97.53	94.18	96.08

C.4.f. Vision and Field of View Testing Measurements

To test for visual performance including near and far acuity, stereo depth perception, color discrimination and vertical and lateral phoria the OPTEC 2000 Vision Tester (Stereo Optical Company, Inc., Chicago, IL) industrial tester was used. The subject looked into the device and responded to 12 different tests. These measurements were collected during the screening visit. See Appendix J for detailed instructions on the use of the OPTEC tester and the datasheet used.

Subjects were also tested for their field of vision at the beginning of one of their testing sessions. The visual field of the subject was also measured using the Inami Stand Perimeter (MK-70, from Franklin Opthalmic Instruments, Romeoville, IL). The subject rested his/her head on a chin rest and the left and right eye were tested separately by covering one eye with an eye patch. A light was introduced (with a density transparency of 1.00 and 4mm^2 in size) and brought towards the center at every 15° for the entire 360°. The subject indicated when the target became visible. The angles were randomly selected until the entire field was tested. The subject was also tested in the center field (< 30°) for blind spots. See Appendix K for detailed instructions on use of the Stand Perimeter and a datasheet.

C.4.g. Subjective Measurements

Perceived exertion and body part discomfort: Subjects were asked their perceived sense of exertion level using Borg's Self-Rating Scale[17] which ranges from 0, which is "very, very light", to 10, which is "very, very hard" perceived exertion (see Appendix L). The subject's were also asked to rank bodily discomfort using a modified Bishop-Corlett diagram[18]. They ranked their back, buttocks, thighs, knees and lower legs on a scale from 0, meaning "no discomfort", to 3, meaning "extremely uncomfortable" (see Appendix M). These subjective measures were obtained immediately following the fatiguing load.

Perceived sense of postural stability index (PSPSI): The PSPSI scale included four questions regarding the subject's experience of postural instability while performing the task on the inclined surface (see Appendix N). The subject answered these questions after each trial. Each question was scored between 0 to 2 by increments of 0.5. Zero meant that he/she perceived no postural instability. The summation of the scores from the four questions defined the overall PSPSI score. Eight meant that they perceived the greatest instability. This summed score was used in the statistical analyses.

C.4.h. Light Meter Readings

A light meter was used to measure the light level in foot-candles (fc) of the testing chamber. A reading was taken prior to the test session while standing on the force platform in the poor and good light conditions (the good light condition was only used for the baseline test). Measurements were taken with the meter placed on the forehead, right cheek, left cheek and at arms length in front of the eyes (this is to represent ambient lighting). The readings ranged from 2.0 to 3.25 fc for "good" lighting and 0.0 to 1.35 fc for "poor" lighting.

C.4.i. Heart Rate Measurements

The subjects were seated at the beginning of each session for approximately 10-15 minutes to allow the subjects to be fully rested before the baseline test. A radial pulse rate was taken for 7 times (every 2 minutes) to establish the subject's resting heart rate. The average of the 7 readings for the radial pulse rate was calculated to estimate the resting heart rate of the subject. Radial pulse rates were also taken immediately after the fatiguing task and postural sway test, respectively, to monitor if the subjects' estimated heart rate exceeded the allowed maximum heart rate for safety reasons. If the subjects' estimated heart rate exceeded the maximum level, the subjects were instructed to stop the test and rest. The maximum estimated heart rate was calculated as [19]:

$$HR_{max} = (220\text{-subject's age}) \times 0.75 \qquad \text{Eq. (2)}$$

The percent maximum heart rate was calculated as [19]:

$$\%\ \text{max HR} = (HR\text{-}HR_{resting}) / (HR_{max}\text{-}HR_{resting}) \times 100 \qquad \text{Eq. (3)}$$

The heart rate measurements for each load task are given in table 4. An example of an upper limit value of 33 is given for an 8-hour shift, which is equivalent to a moderate workload is given by Kodak [19].

Table 4. Average percent maximum HR for the loading tasks.

Load	% max HR	s.d.
Full	45.8	22.0
Half	39.5	21.0
None	12.8	10.5

C.5. Final marker system for the study

The following 16-point marker system was adopted. Sixteen markers were placed on the following anatomical positions: Two each at (1) Top of first toes, (2) fifth metatarsophalangeal (MTP) joints, (3) heels (calcaneus), (4) Knees (fibular head), (5) hips (greater trochanter), (6) shoulders (acromion process), (7) elbows (lateral epicondyle), and (8) wrists (styloid process). The markers used at the first toes and the fifth MTP were used to define the stability boundary (SB) as per our earlier studies (Final Reports for Fall Potential of Work on Elevated and Inclined Surfaces, R01-OH0317 and Ergonomics Task Performance on Slippery Surfaces, R01-OH03079) . Four markers were placed on the standing surface. The marker system is shown in Appendix O.

C.6. Experimental Procedures

C.6.a. Phase 1: Specific Aims #1 and 2

A custom designed computer program, *Lines on Demand (ver.2.0.5)*, was used to randomly generate images of horizontal and vertical lines. Each subject performed a total of nine trials in a testing session. The trials were blocked by incline and the first load on the incline was "no load" with the remaining two loads completed in random order. The order of the inclines was also randomized. Each trial the subject completed the designated fatigue load in an area adjacent to the testing chamber. Immediately after the load the subject was asked to rate his/her perceived discomfort and exertion. The subjects were then asked to stand on the inclined surface. Next, the *Lines on Demand* program was initiated and the subject responded by saying "tilt left", "tilt right" or "down left", "down right" to the lines generated. These responses were directly entered into the computer. Upon completion of the test, the subject was asked to rest, seated in a chair, until the next trial. During the entire testing session, the heart rate was logged using a real-time heart rate monitor as a safety precaution. Seventy-five percent of the maximum heart rate was used as a ceiling value for the subject's heart rate during the session to stop the experiment for the safety of the subject.

A total of 42 images were presented randomly and evenly divided between horizontal and vertical. The angles presented ranged from -10° to 10° to the "dead" line, perfectly vertical or perfectly horizontal, at 1° intervals for both the horizontal and vertical directions. The images were displayed from the computer via an overhead projection system. The subject stood in a darkened room in a black enclosure that was 8 feet deep and 12 feet wide. The projection system was placed behind and slightly to the left of the subject and projected the images of lines to the front wall of the enclosure (see figure 5). The edges of the display were concealed so that it appears circular and offer no additional visual cues to be referenced by the subject. Subjects

were asked their perceived sense of exertion level their bodily discomfort. These subjective measures were obtained immediately following the fatiguing load.

C.6.b. Phase 2: Specific Aims # 3 and 4

In the phase 2 experimental protocol, each subject performed ten trials. The first trial was the baseline with the remaining 9 trials consisting of three workloads (none, half and full) and three inclines (0°, 14° and 26°). Each trial was divided into two tasks, stationary and reach with each task lasting 30 seconds. The trials were blocked according to the incline with the load within the block performed in random order. For each load, the task was performed in random order. The baseline trial was the two tasks completed at 0° and no load in good lighting. During each trial kinetic, kinematic eye movement data, radial heart rate and perceived sense of fall, discomfort and exertion were recorded. In addition, a self reported checklist (Appendix D), session interview (Appendix D) and light meter readings were taken for each subject prior to the session.

C.6.c. Phase 3: Specific Aim # 4,5,6 and 7

The phase 3 protocol included a total of five sessions. One session included the Emax and Vmax tests. The other four sessions were postural balance sessions. These sessions are described in the following sections.

C.6.c.1. The Estimated Maximum Displacement of Center of Gravity Measurement Test (EMAX)

To measure the maximum displacement in the anterior direction before a fall occurs, the EMAX test was completed for all subjects in Phase 3. The EMAX was used to quantify the Functional Stability Boundary and the calculation of IPSB. Each subject stood on the force platform with his/her arms extended in front. A foam board was suspended in front for the subject to "push" on (see figure 7). The subject was instructed to fall forward, only rotating about the ankle, until he/she must step forward to maintain upright balance. The subject was allowed to practice several times and three trials were collected. Kinetic, kinematic and EMG data were collected during the trials.

C.6.c.2. Maximum Voluntary Contraction (MVC) Test (Vmax Test)

The Vmax test was performed for EMG data normalization. In the Vmax test, three MVC's of the 8 muscle groups of the lower limbs were measured. Prior to the Vmax test, three resting EMG trials were recorded for 10 seconds for data normalization. For the resting EMG trials, subjects were instructed to sit on a chair with their knees extended in a relaxed position, as shown in Figure 14. There was approximately 2 minute interval between each resting trial. During the Vmax, the subjects were instructed verbally by the staff to contract the muscle being tested to the maximum for approximately 3 seconds (Ericson et al., 1985). The force of the muscular contraction was recorded using a load cell with custom software. Once a Vmax trial started (i.e. the EMG recorder started recording), the operator observed the force output and instructed the subject to contract the muscle being tested to the maximum. When the force output reached its maximum, the operator instructed the subject to hold the contraction for approximately 3 seconds. If the output forces during the 3 sec. maximum contraction period exceeded one standard deviation of the forces recorded, the trial was repeated. The starting and ending times of the maximum force recording and the average force for the trial were manually recorded and entered into an Excel worksheet for calculations of the maximum EMG amplitudes. After each Vmax trial, the subject was asked to relax for approximately 2 minutes for recovery

before the next trial. The Vmax testing positions for the muscles are summarized in Appendix P.

C. 6.c.3. Postural Balance Sessions

During each postural sway test session, each subject underwent each of the three levels of fatigue prior to performing a postural sway test on three inclined surfaces (0°, 14° and 26°). A session interview (Appendix D) and the self-reported workloads questionnaire (Appendix D) were administered by the tester at the beginning of the session. After the session interview and prior to the test, bipolar surface Ag/AgCl electrodes were placed on each muscle 4 cm apart at standard positions [20, 21]. Prior to placing the electrodes on the muscles, the skin surfaces of the muscles were rubbed and cleaned with alcohol pads to remove dead skin cells [22]. The electrodes were securely attached by Teflon adhesive micropore tape.

Upon completion of the fatiguing task (full, half or no), the subjects were asked to rate their body discomfort and total exertion for the task. After rating the body discomfort scale and overall physical exertion level, the subjects were instructed to step onto a force platform with one of the three inclined surfaces mounted on it. The subjects stood on the inclined surface for 30 seconds for a postural sway test while performing one of the two tasks (reaching forward or standing quietly) in one of the two visual cue settings (with or without H-shaped visual cues in a dark environment). Prior to the test, the subjects were instructed to stand on the force platform in a relaxed and balanced posture with their feet apart approximately at the shoulder width and their hands on their hips. Once the subjects finished each sway test, the PSPSI was administered. A typical experimental set-up is shown in Figure 15.

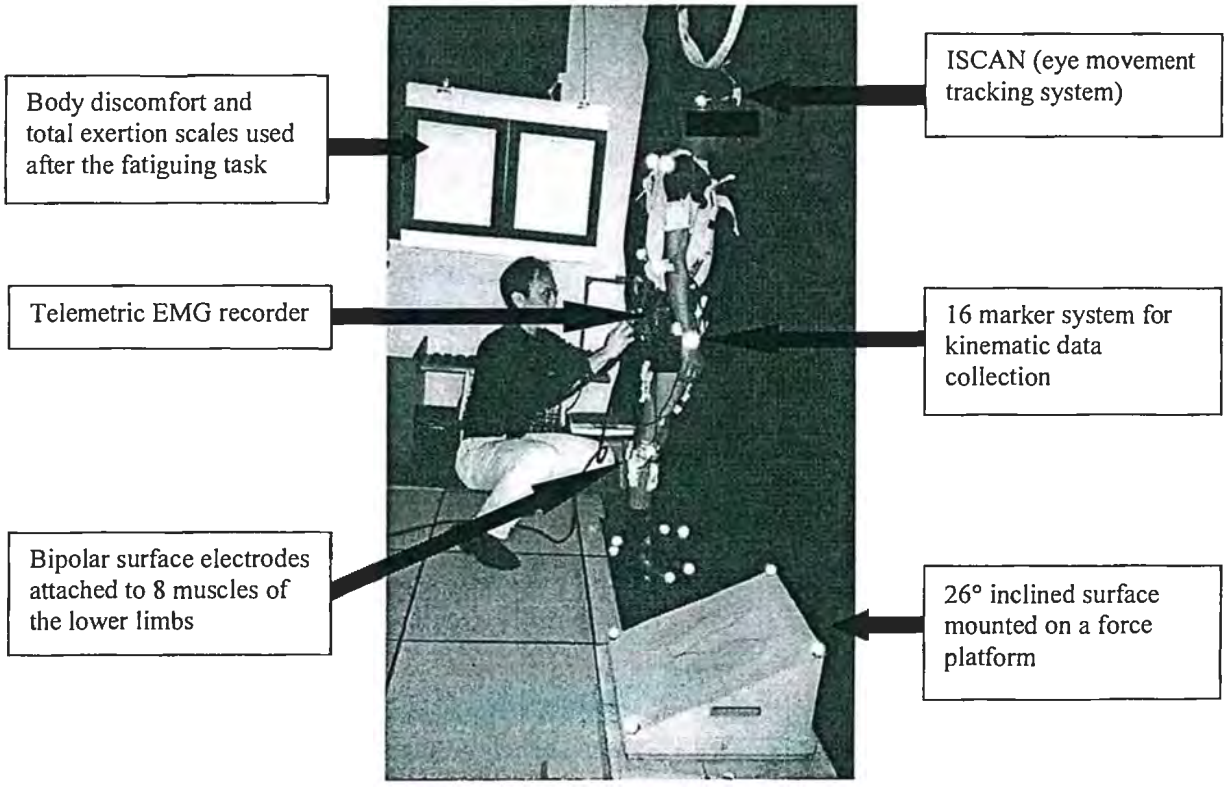


Figure 15. A typical experimental set-up for Phase 3

C.6.c.4. Pilot tests

C.6.c.4.i. Before and After Work Pilot

Since our subject population was workers, their testing sessions were scheduled as convenient as possible for the worker. To determine if testing the worker before or after their regular work shift affected the testing, a pilot test was conducted. One of the four balance sessions was repeated for five subjects. The repeat session was completed at the opposite time. For example, if the original session was completed before the subject went to their regular work or on his or her off day, the repeat session was scheduled after their full work shift.

C.6.c.4.ii. Fatigue Pilot Test

Due to the fact that data storage capacity of the telemetric EMG recording system was too limited to record the EMG activities of all 8 muscle groups of the lower limbs during the fatiguing task and postural sway test (refer to Section C.2.b.1. postural sway testing procedure), the EMG activities of the 8 muscles were not recorded during the fatiguing tasks, but during the postural sway testing. To investigate the effect of the fatiguing tasks performed in the present study on the EMG activities of the 8 muscle groups, a fatigue pilot test was carried out. In the fatigue pilot test, static localizing muscular fatiguing tasks were performed by five subjects. The 8 muscle groups included the left quadriceps (LQ), right quadriceps (RQ), left hamstrings (LH), right hamstrings (RH), left tibialis anterior (LT), right tibialis anterior (RT), left gastrocnemius (LG) and right gastrocnemius (RG).

Figure 16. Resting posture for resting EMG data collection on the leg muscles

Prior to the first fatiguing task, the subjects were seated in a sitting position for approximately 10-15 minutes to allow the subject to be fully rested (Figure 16). A resting heart rate and EMG were obtained. EMG activities of the 8 muscle groups were recorded during the three levels of fatigue. Each level of fatigue (full, half and no) was performed three times. The fatigue levels were assigned to the subject at random. As a result, a total of 9 random fatiguing tasks were performed by each subject for the fatigue pilot test. All the subjects were rested in a standardized resting position, as shown in Figure 16, for at least 2 minutes between trials until they were fully rested, as indicated by their resting heart rate and that they felt comfortable for the next trial. The EMG data sampling periods for full, half and no fatigues were set at the subject's corresponding maximum, half and maximum fatiguing time periods, respectively.

C.7. Dependent Variables

C.7.a. Phase 1: Specific Aims #1 and 2

For the Phase 1 experiment, the dependent variable was the response to the angle of the line presented to the subject (correct or incorrect).

C.7.b. Phase 2: Specific Aims # 3 and 4

C.7.b.1. Kinetic Data

Determination of Postural Sway and Instability Objective Measures of Postural Sway: Sway area (SA) is the area of the projection of the body's CP on the xy plane due to sway, and sway length (SL) is the distance traveled by the CP. We have used these variables in several research studies in our laboratory [16,23-28]. Sway Fy (RMS) [also known as F(AP)] and Sway Fx (RMS) [also known as F(ML)] are the root mean square values of the horizontal forces in the AP and ML directions respectively. The definition of Maximum Sway AP Excursion and Maximum Sway ML Excursion are given in the following.

Excursion Parameters: The excursion parameters are defined on the basis of the lateral and medial deviation of the center of pressure (CP) trace under the feet during static task performance. Figure 17 shows the trace of the movement of the CP under the feet. The medial lateral (ML or x-direction) excursion is the net deviation of the CP in the ML direction. The anterior posterior (AP or y-direction) excursion is quantitated by measuring the net deviation of the CP in the AP direction. The excursion parameters quantitate the extent of movement of the point of application of plantar force under the supporting feet. This movement of the CP under the foot is a time variant response to the momentary position of the whole-body center of gravity (CG) with respect to the basal supporting area provided by the feet. Thus, the excursion parameters provide an indirect measure of the dynamic stability performance during the posture.

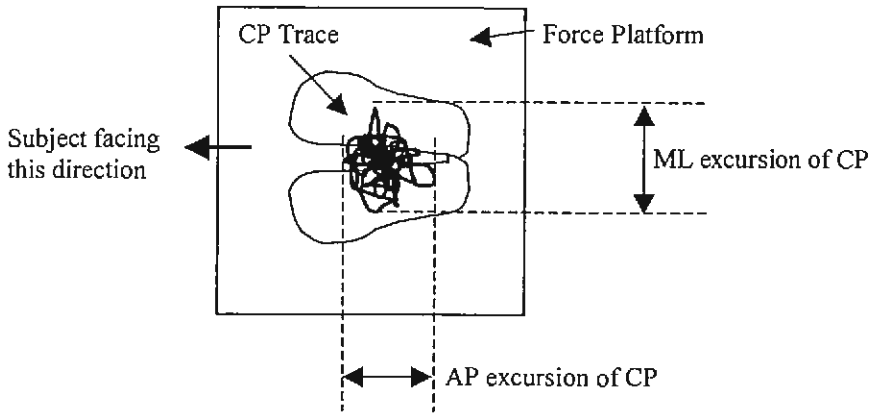


Figure 17. Excursion of CP in the ML and AP directions

C.7.b.3. ISCAN data

Descriptive statistics on plane intersection data was collected. The frequency count for each of the twelve planes was used for analysis.

C.7.c. Phase 3: Specific Aim # 4,5,6 and 7

C.7.c.1. Postural Balance data

The same postural stability variables of sway length, sway area, excursion in the ML (x) and the AP (y) as phase 2 were used for Phase 3. Three non-dimensional indices, which are similar to those described by Bagchee et al[25], were used to quantitatively determine the propensity of momentary loss of postural instability associated with a sway pattern formed by the CG with respect to the postural stability boundary (basal support area). The stability boundary used to determine CG based postural instability was used for dynamic tasks and are described in our earlier publications [25, 26]. The two variables used to describe the propensity of postural instability are described as follows:

Index of Proximity to Stability Boundary (IPSB): IPSB measures how close the body's CP or CG travels to a person's stability boundary, which is graphically shown in Figure 18, respectively. The equation is as follows:

$$IPSB = \frac{p}{Rmax} \qquad \text{Eq. (4)}$$

where,
p = the minimum distance between the stabilogram and the stability boundary.
R_{max} = the radial distance of the point on the stability boundary that is closest to the CP or CG movement (Figure 18).

A lower value of IPSB indicates that the subject has a greater propensity of postural instability while performing a given task. A negative value of IPSB implies that subjects' CP or CG are outside of the stability boundary.

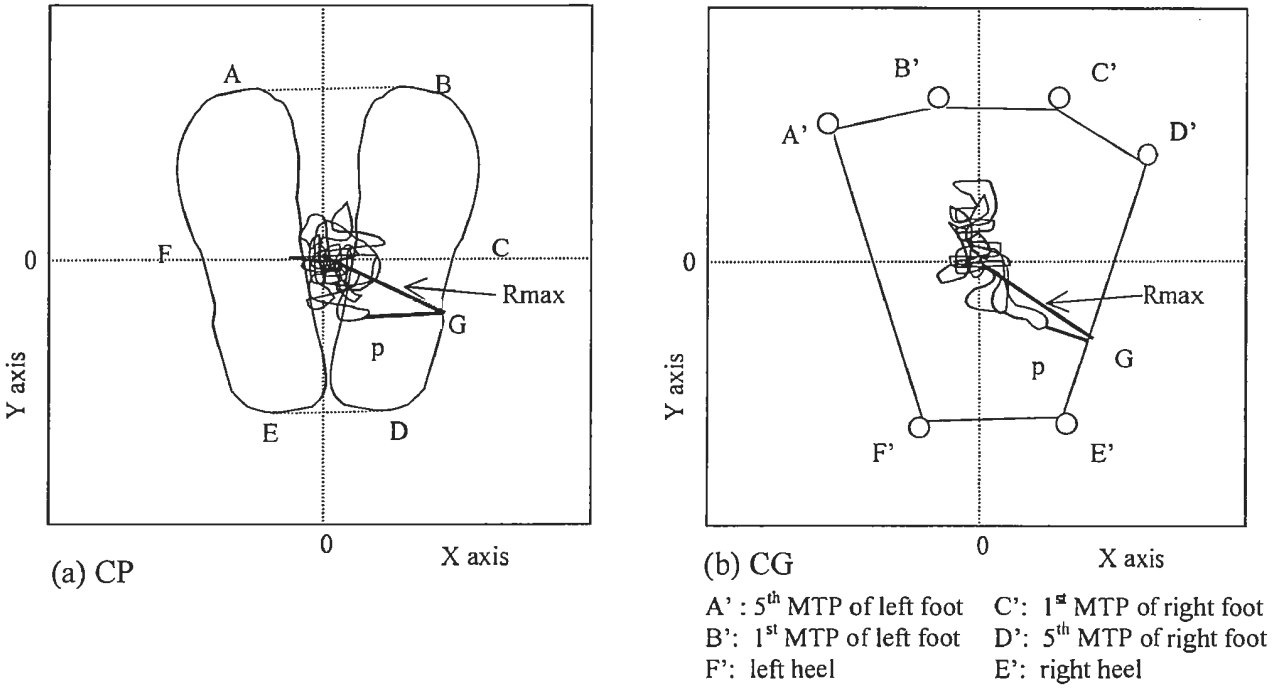


Figure 18. CP (a) and CG (b) based IPSB and Stability Boundary

Weighted Residence Time Index (WRTI): WRTI is the weighted measure of time that the subject's CP or CG lies in various proximity zones to the stability boundary. The proximity zones (200%, 180%, 160%, 140%, 120%, 100%, 80%, 60%, 40%, and 20% distances of the stability boundary from the center) are constructed by drawing concentric lines to the stability boundary at the predetermined distances. The greater the residence time in the outer proximity zones, the greater is the propensity of postural instability for a given task under specified intrinsic and extrinsic conditions. The equation for determining WRTI is shown in the following:

$$WRTI = K \Sigma e^{i} z_i \qquad \text{Eq. (5)}$$

where z_i = frequency count of zone i
$i = 3, 4, 5, 6, 7, 8, 9, 10.$
$K = e^{-4}$

Stability Area Ratio:
In addition to the proximity of the stabilogram to the functional stability boundary (FSB), it is also important to consider the spread of the stabilogram in comparison to the FSB. This comparison provides a composite estimation of the CP or CG sway during the entire interval of the task. A ratio of the areas is described as a non-dimensional stability area ratio (SAR):

$$\text{Stability area ratio (SAR)} = A_t / A_{sb} \qquad \text{Eq. (6)}$$

Where A_t = area of the envelope around the stabilogram
A_{sb} = area of the FSB

A larger spread of the stabilogram will result in a higher the value of SAR, which implies the greater the risk of the CP approaching the stability boundary and relatively higher postural instability.

C.7.c.2. ISCAN data

In the ISCAN data, there were some data points that were not valid eye movements. These invalid data points occurred during a blink or when either the pupil cross hair or corneal reflection crosshair was off the correct position. The pupil cross hair was sometimes deflected onto the eyelashes or lost if the subject was looking down and the upper eyelid covers the pupil. The corneal reflection cross hair was sometimes deflected to another reflection in the eye such as a tear, the eyelid, or reflections from the infrared lights used to videotape the kinematic data.

Four types of data were categorized from the ISCAN data. These include: **(1) blink data:** these were still valid data but indicates that the subject was not receiving any visual input since the eyes were closed; **(2) invalid data:** the eyes were open but either one or both of the crosshairs were off the proper position on the eye so the data is an artifact; **(3) valid data:** the eye was open and both the pupil and corneal reflection crosshairs were in the proper position and **(4) off data:** these were valid eye movement data, but the subject was looking off of the defined planes. To categorize these types of data, criteria were developed using the information from the raw output data files from ISCAN.

A blink data point can be determined directly from the raw file. Also, after looking at typical data, it was found that data points immediately following a blink might not be valid due to time taken for the cross hairs returning to the correct position. These data points were labeled a blink even though they were not indicated as a blink in the raw file. The criteria for valid data points are the angle of elevation and azimuth. The ISCAN software and hardware specifications set the eye movement tracking and limits eye angle to approximately $\pm 25°$. Therefore, if an angle exceeds these limits, in either azimuth or elevation, the data point is rendered invalid. From the valid data points, it was found that some had coordinates of (0,0,0). This indicates a valid eye

movement, but the subject was looking away from the predefined planes. The following summarizes how the data is categorized: **"Blink"** for a blink data point or a data point immediately after at least 4 blink data points that exceeded the angle limits but was at least 10 data points after. This criterion was set after observing that the tracking of the pupil and crosshair did not immediately resume after a blink but took a few points but never more than 10 points. **"Valid"** for a data point that was not a blink and did not exceed ± 25° in either the azimuth or elevation eye angle. **"Off"** for a valid data point with (0,0,0) as the x, y, z coordinates (found in the *.dxf output file). **"Invalid"** for a data point was not a blink and exceeded ± 25° in either the azimuth or elevation eye angle.

The valid data points were then used to calculate the outcome measures used in the analyses in Phase 3. Custom software was developed which checked the data for valid points and then processed the valid data (see Appendix Q for ISCAN Analysis program description). Figure 19 shows a schematic of the program. Outcome measures include the following and the validation for each outcome measure is described in Appendix R: **Length:** the length of the eye movement path of valid data points, the total distance between the valid data points going sequentially through them. **Area:** the area that includes all valid data points. The outer points were found by the convex hull algorithm and area calculated by triangularization. This area was found to be a gross estimate of the area. A modification was made to the convex hull algorithm that made the area calculation more accurate. A complete description of this can be found in the validation in Appendix R. **Clusters:** The clusters were determined by going sequentially through the valid data points and seeing if the next data point is within the radius set in the parameter file (see program description in Appendix Q). If it is, it counts in the cluster and a mean coordinate to test the next point is calculated. The next point is then tested to see if it is in the cluster as well. If it is not, then the next point begins the next cluster. This testing continues until all valid data points are tested. The data given for each cluster includes the number of points in the cluster, the mean y and z position for that cluster and the duration. The total duration is calculated from the number of data points multiplied by the duration in the parameters section. The mean duration is the average duration of each data point. At least three data points are required to make up a cluster. Otherwise, it is a pair (two data points) or a singleton (one data point). **Fixations:** Every coordinate (y,z) that has a cluster, pair or singleton in it, is then described as a fixation. A fixation may include several clusters, pairs or singletons since the fixation do not have to be sequential in time. The y and z coordinates, the number of data points in that fixation and the cumulative fixation time (which is the sum of the durations for all the data points in that fixation) is given.

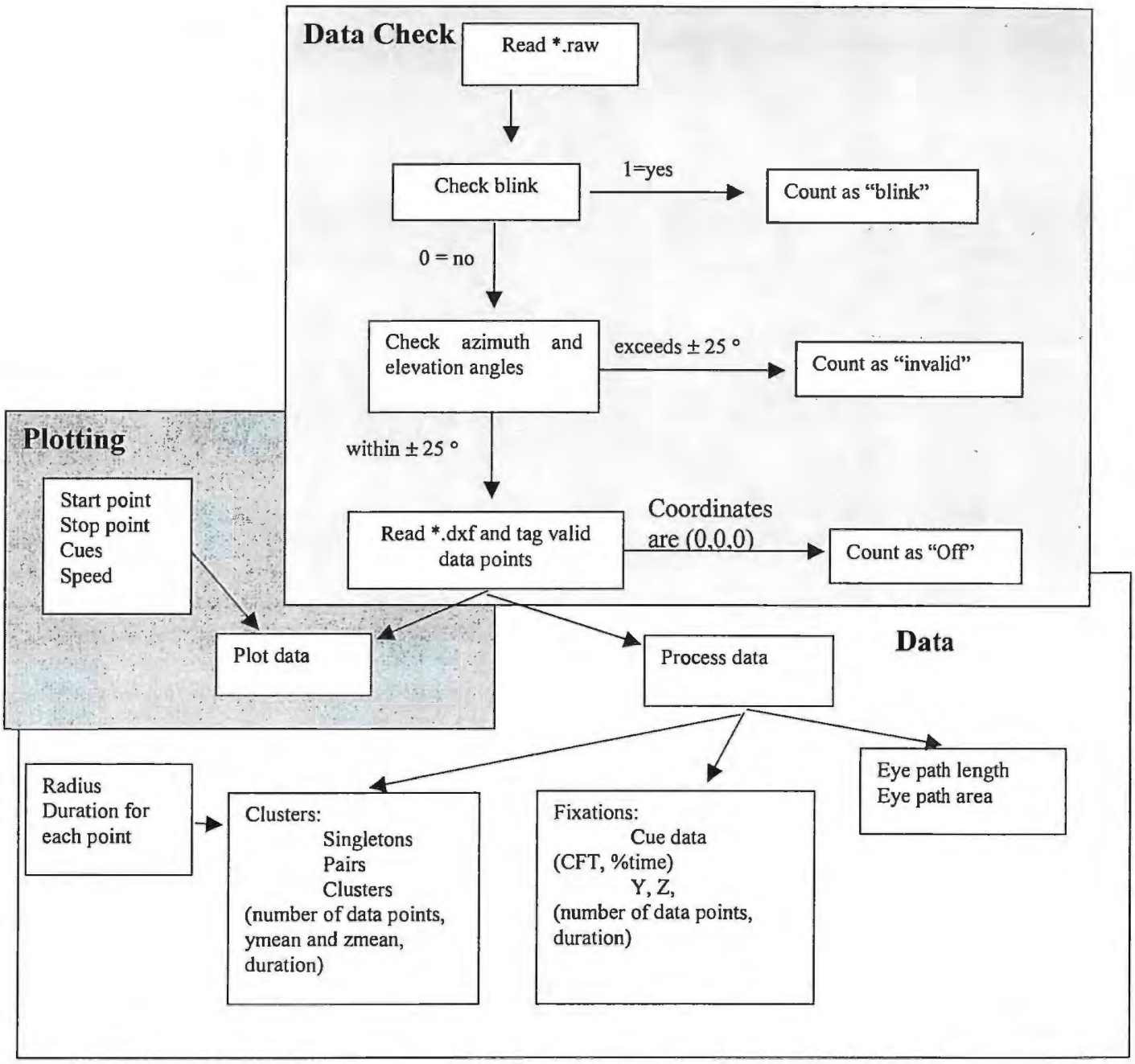


Figure 19. Schematic of the ISCAN analysis program.

For the statistical analysis, the eye movement variables were modified slightly. Since not all data points were valid in a trial, some variables were "weighted" as to the number of valid data points. The following table 5 has descriptive statistics on the ISCAN data for Phase 3. The stationary tasks had a higher percentage of valid data points (87.9%) than reach (71.2%) since the subject's tended to look down during the reach task.

Table 5. General ISCAN data description (all trials and reach vs. stationary trials).

	All trials		Reach		Stationary	
	Mean (s.d.)	% (s.d.)	Mean (s.d.)	% (s.d.)	Mean (s.d.)	% (s.d.)
#. of data points in trial	1849.6 (228.4)	----	1850.9 (247.6)	----	1848.6 (211.62)	----
Valid data points	1474.6 (415.1)	80.5 (22.4)	1303.5 (421.9)	71.2 (22.8)	1613.9 (352.8)	87.9 (19.0)
Zero data points	129.2 (108.6)	10.1 (9.8)	135.41 (93.4)	11.5 (8.8)	124.2 (119.0)	8.9 (10.4)
Invalid data points	205.4 (322.7)	11.2 (17.7)	327.2 (339.2)	17.9 (18.6)	106.3 (271.0)	5.8 (14.9)
Blink data points	150.4 (243.2)	8.3 (13.5)	196.1 (260.5)	10.8 (14.5)	113.3 (221.4)	6.2 (12.3)

In addition to weighting the variables, the fixations on the cues were of interest in this study. The data was run through the analysis software several times to collect information on the number of data points on the cues, and areas around the center cue. The areas around the right and left cues were not investigated further since no data points were on them and the center cue extends out to the right and left cue. Table 6 shows the percent fixation time for each area.

Table 6. ISCAN Cue fixation data for all trials.

Fixation Location	% fixation time (s.d.)
Left cue	0
Right cue	0
Center cue	21.5 (25.3)
No cue	53.9 (26.9)
Out of no cues.....	
0-5" above/below center cue	28.2 (28.0)
5-10" above/below center cue	13.7 (16.9)
10-15" above/below center cue	9.9 (15.5)

For the cluster analysis, different criteria was set for describing the cluster beginning with a radius of 1.2 inches, which was determined by the accuracy of the ISCAN device. The data was ran through the program several times to complete the cluster analysis with a criteria of 1.2", 2.4", 4.8" and 9.6". Descriptive results of the cluster analysis is shown in table 7. Since the cluster analysis with a radius of 9.6" included 99% of the data, it was selected for use in the final analysis.

Table 7 . Descriptive statistics for different radius criteria for the cluster analysis of ISCAN data.

radius	number of clusters (s.d.)	number of datapoints in a cluster (s.d.)	percent of datapoints in a cluster (s.d.)
1.2 inches	84.0 (41.7)	1201.9 (457.7)	88.5 (13.6)
2.4 inches	54.2 (30.8)	1225.9 (435.8)	94.3 (9.9)
4.8 inches	33.9 (22.4)	1181.3 (432.8)	97.4 (9.9)
9.6 inches	19.1 (14.6)	1066.2 (465.5)	98.7 (5.9)

The following section describes the eye movement variables that were used in the final statistical analysis:

RMS velocity: This was the root mean square of the resultant velocity of eye movement. The velocity in the elevation and the velocity of the azimuth was given in the *.raw output of the ISCAN program.
RMS acceleration: This was the root mean square of the resultant acceleration of eye movement. The acceleration in the elevation and the acceleration of the azimuth was given in the *.raw output of the ISCAN program.
Weighted eye length (cm): This was the eye movement length given from the ISCAN analysis program divided by the number of valid data points minus the zero data points in a trial.
Weighted eye area (cm^2): This was the eye movement area given from the ISCAN analysis program divided by the number of valid data points minus the zero data points in a trial.
Weighted 9.6" cluster distance (cm): The distances of the clusters in a trial were determined by using the mean coordinate of each cluster, calculating the distance to the next cluster. These distances were then summed. This sum was weighted buy dividing it by the number of clusters minus 1.
Center Cue %: The percent of data points on the center cue area.
0-5" above/below center cue %: The percent of data points on the area 0-5" above and below the center cue.
5-10" above below center cue %: The percent of data points on the area 5-10" above and below the center cue.
10-15" above/below center cue %: The percent of data points on the area 10-15" above and below the center cue.

C.7.c.3. EMG data

Once an EMG signal has been recorded, processing of the signal follows. The first level of processing is known as filtering. This can be accomplished by an analog (in the EMG recorder) or digital (in the software) filter. As mentioned previously, 60 Hz noise occurs from electrical cables in the recording environment. A notch filter (a band reject filter from 59-60 Hz) can be used to filter out the 60 Hz noise [29]. Another type of filter is the bandpass filter, that is used to filter certain ranges of EMG signals to allow a researcher to ignore miscellaneous biological or motion artifacts. Selecting filters is an art because some filters are better than others in some applications, depending on the muscle of interest and analysis approaches.

After unwanted signals have been filtered out, the next step is to process the signals. The main purpose of signal processing is to obtain information relevant to the experimental question. To ensure signal fidelity, it is recommended that a low noise, high input impedance, linear amplifier with a bandwidth from 1 to 3000 Hz and a proper gain to amplify the EMG signal to one electrical voltage be used [30]. Winter has summarized EMG processing methods as presented schematically in Figure 20 [31]. These methods are as follows:

1. Raw EMG display: is primarily used for clinical applications or validation of the EMG recording (reported in mV).
2. Full wave rectification: absolute values of the EMG are generated by full-wave rectification. The rectified signal does not cross through zero and therefore it is a good indication of the change in EMG amplitudes that are related to muscular contraction level (reported in mV).
3. Linear envelop: filters the full-wave rectified signal with a low-pass filter. It is a "moving average," since it follows the trend of the EMG and resembles the shape of the tension curve (reported in mV). Winter pointed out that calling the linear envelop an integrated EMG is incorrect, as it can be confused with the calculus use of the term "integrated," a different form of processing.
4. Integrated EMG (iEMG): is the integration of the full-wave rectified signal (reported in mV-s). Another form of iEMG involves a resetting of the integrated signal to zero at certain intervals of time (40-200 ms), which yields a series of peaks representing the trend of EMG over the previous time interval. The series of the peaks is called a "moving average." IEMG is sensitive to the time constant of the integrator. The shorter the time constant, the greater the variability in the output [32]. It has been recommended that the time constant for iEMG be 50 to 75 ms [33].

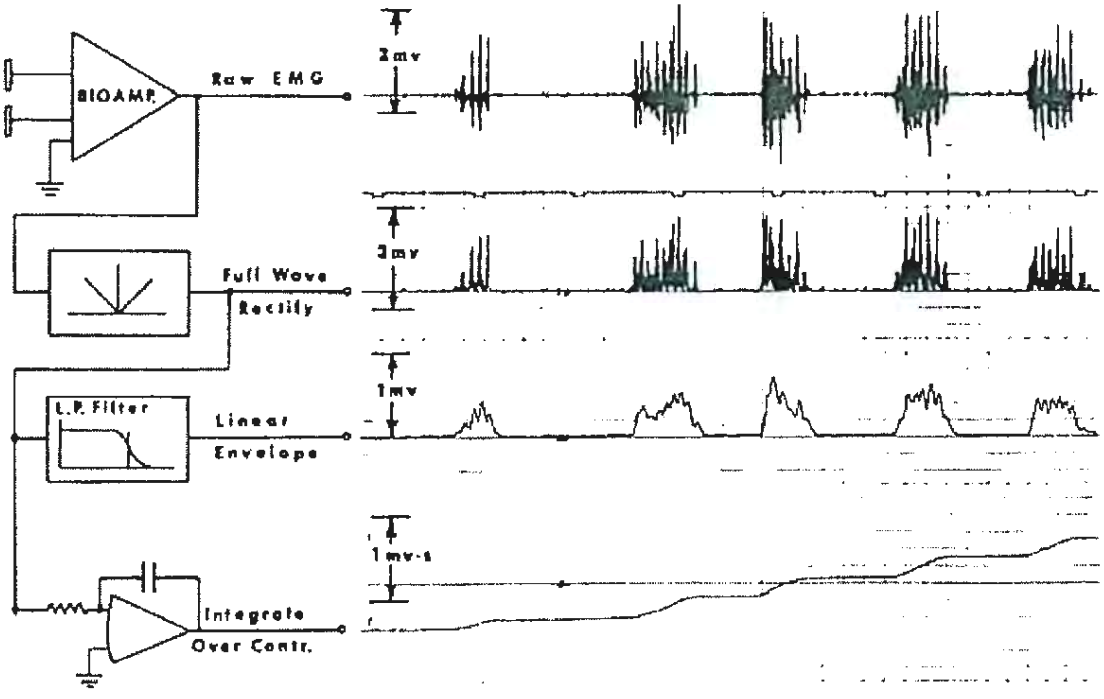


Figure 20. Illustration of EMG signal processing methods (adapted from Winter, 1990)

The root-mean-square (RMS) algorithm is widely used in engineering applications. It has also been increasingly used in EMG signal processing because it has been demonstrated to be more relevant to muscle tension than is full-wave rectified or iEMG signals [34]. The unit of the RMS EMG is mV.

Another form of EMG signal processing is via transformation of the EMG signal from the amplitude to frequency domain. Of many transformations, the Fast Fourier transformation (FFT) is most commonly used in EMG signal processing due to its general and diverse applications [30]. The characteristics of the transformed frequencies depend on the recorded summation of the active EMG signals in the underlying muscle. The content of the frequencies is related to the numbers of active action potentials and their constituent firing rate [32]. Therefore, measures based on the frequency content of the EMG signal are often used to describe physiological or pathological phenomena. The measures used in the literature include mean frequency, median frequency (MF) [34-36], and ratio of high to low frequencies [37,38], and percent of frequency shift in a band from 4-30 Hz [39]. The use of the measures for evaluation of fatigue is described in Section D.3.

Amplitude probability density function (APDF) analysis was first used by Jonson to quantify the relative probability of a given EMG amplitude [40]. In this method, the EMG signal of a trial is normalized to be 1 for the maximum amplitude of EMG during a maximum isometric contraction performed for each muscle in a standardized position. The amplitude of the curve can be submitted to either a RMS or full-wave rectified analysis. An example of the APDF and cumulative APDF curves are shown in Figure 21. A cumulative APDF curve is the integration of the area under the APDF curve. The advantages of using APDF analysis are three-fold: (1) muscular contraction type (low amplitudes over a long duration vs. high amplitudes over a short duration) can be determined from APDF analysis, (2) percentage of the time the muscle is at a certain amplitude or less can be determined, and (3) changes in the APDF curve over time can be used to quantify fatigue or adaptations as a result of fatigue [41]. Generally, a shift of the cumulative APDF curve to the right is an indication of an increase in EMG activity. APDF analysis has been used in many studies [40-44]. Veiersted [43] found that the APDF curve of the RMS amplitudes during a long duration of sampling should be bimodal, as opposed to being unimodal or normally distributed. He also found that workers who do not show the rest peak in the APDF curve tend to develop muscle pain or tension myalgias. Another study has shown that the 90th percentile values of the cumulative APDF curve were well correlated with force and finger flexor and extensors EMG [44].

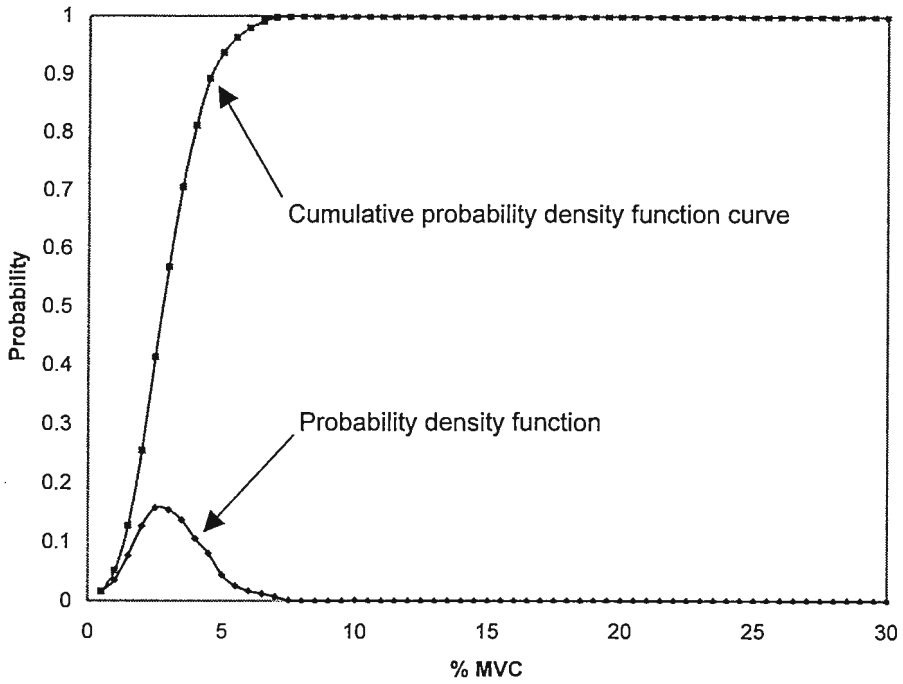


Figure 21. Sample amplitude probability density function curves. The relative probability of a given EMG amplitude can be determined from the cumulative probability density function curve

D. RESULTS AND DISCUSSION

D.1. Phase 1 Results and Discussion

Descriptive statistics for the demographics of subjects that participated in Phase 1 are shown in Table 8.

Table 8. Demographics for Phase 1 subjects by experience.

	Inexperienced	**Experienced**
N	30	30
Age (years) ± s.d.	39.2 ± 10.1	40.6 ± 9.8
Height (cm)± s.d.	173.0 ± 8.7	172.3 ± 8.8
Weight (kg) ± s.d.	86.4 ± 17.4	87.4 ± 18.5
Gender	15 F and 15 M	11 F and 19 M

Three different models were run including either the Borg's perceived exertion level (0 to 10), the discomfort (the sum of the responses for the five body parts or 0 to 15) or the fatiguing load (none, half and full) as an independent variable. These were run in separate models since they are all an indication of the load, as the subjective responses of discomfort and exertion are the

"dose" and the fatiguing load is the "exposure". Covariates used in all initial models were gender, race (black or white), age (years), reaction time (seconds), and the lagtime it took for the subject to respond when an angle was presented (seconds).

For the model with the fatiguing load variable included, the full and half load significantly decreased the number of correct responses of identifying the angle (p= 0.0307 and p=0.0242, respectively) compared to no load. Age, job experience and the lagtime were also significant (p=0.0001, p=0.0208 and p=0.0007, respectively). For the model with Borg's perceived exertion level, the exertion level marginally significantly decreased (p=0.0669) the number of correct responses of identifying the angle. Age, job experience and the lagtime were also significant (p=0.0001, p=0.0209 and p=0.0013, respectively). For the model with the discomfort variable, no significance was found for discomfort, but age, job experience and lagtime were significant (p=0.0001, p=0.0234, and p=0.0018, respectively). The following tables 9,10 and 11 show these results. Figures 22 and 23 show the effect of the load and age on the probability of responding correctly by job experience. Figures 24 and 25 show the effect of the load and age on the response time by job experience.

Table 9. Phase 1 Regression Model with load.

Variable	Parameter Estimate	p-value
100% load	-0.1095	0.03*
50% load	-0.1095	0.02*
Job experience (months)	0.0018	0.02*
Incline 26°	-0.0340	0.53
Incline 14°	-0.0241	0.68
Age	-0.0373	0.00*
lagtime	-0.2850	0.00*

Table 10. Phase 1 Regression Model with perceived exertion.

Variable	Parameter Estimate	p-value
Perceived exertion	-0.0138	0.07
Job experience (months)	0.0018	0.02*
Incline 26°	-0.0317	0.56
Incline 14°	-0.0182	0.76
Age	-0.0372	0.00*
lagtime	-0.2693	0.00*

Table 11. Phase 1 Regression Model with discomfort.

Variable	Parameter Estimate	p-value
discomfort	-0.0098	0.14
Job experience (months)	0.007	0.02*
Incline 26°	-0.0309	0.57
Incline 14°	-0.0166	0.78
Age	-0.0371	0.00*
lagtime	-0.2653	0.00*

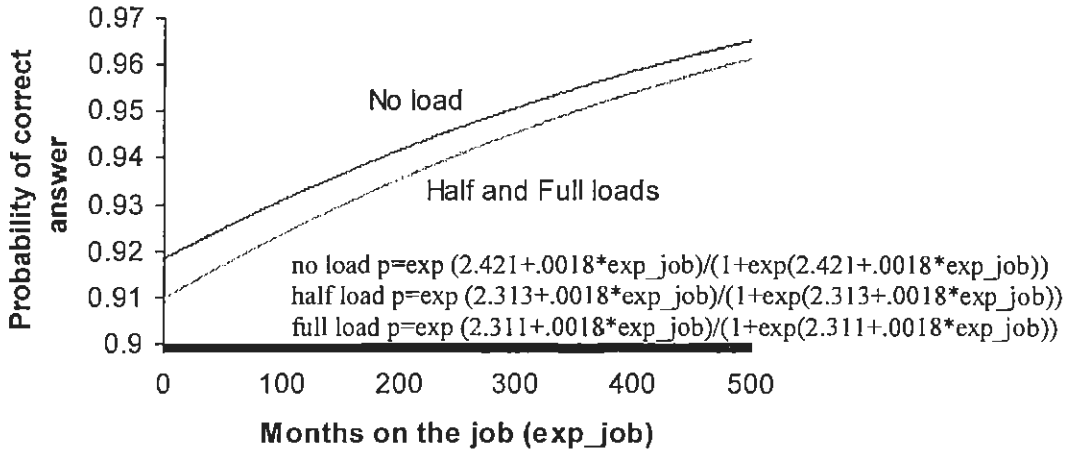


Figure 22. The effect of load on the probability of responding correctly by months on the job (exp_job).

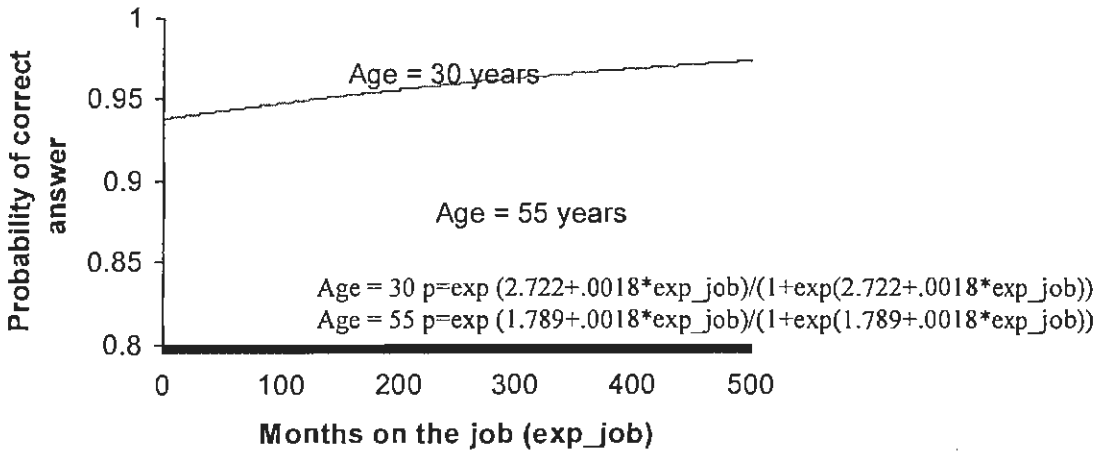


Figure 23. The effect of age on the probability of responding correctly by months on the job (exp_job).

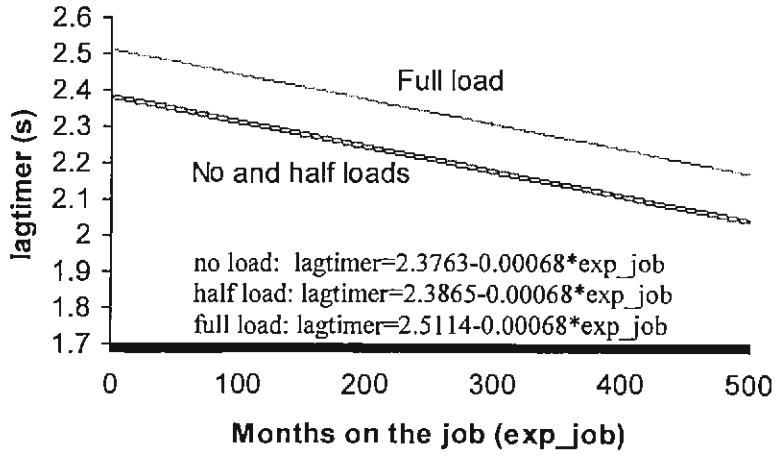


Figure 24. The effect of load on the response time (lagtimer) by months on job (exp_job)

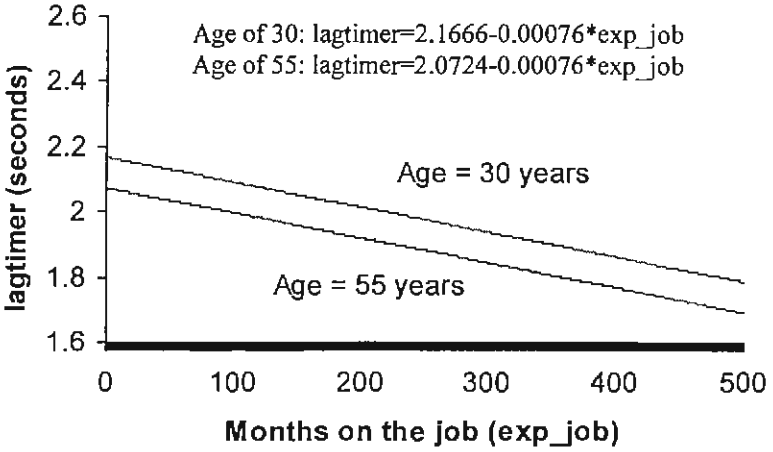


Figure 25. The effect of age on the response time (lagtimer) by months on the job (exp_job).

D.1.a. Summary of Findings/Implications From Phase 1

These results indicate that with more months of job experience on inclined and/or elevated surfaces, subjects were able to more accurately perceive the angle presented. Also, younger workers and those who took more time answering were able to more accurately perceive the angle presented (see figures 23 and 25 above). This indicates that workers may be able to adapt their visual spatial perception (VSP) with work experience on inclined and/or elevated work surfaces. This also demonstrates that with age, VSP may become weakened. Visual acuity

decreases in people age 20 to 50 years and after 50 years, decreases very rapidly. It is expected that taking more time would lead to more correct responses and this emphasizes the safety risks of hurried tasks or actions on the job. For the fatiguing effect, the half and full load significantly decreased the number of correct VSP responses (see figures 22 and 24 above). The subjective responses of discomfort and exertion did not show any significant changes in VSP, but did show a trend that as perceived discomfort or exertion increased, the VSP response decreased. This experiment tested acute muscular fatigue. Future experiments may include mental fatigue and more chronic muscle fatigue. Fatigue, both physical and mental is often a problem in the workforce, especially at the end of a shift. By perceiving the angle correctly, the postural balance will be more stable since the person is accurately perceiving the visual cues available to orient him/her self. This study showed that experience, fatigue, age and response time was important for a worker to accurately perceive the visual-spatial environment. Future research with objective measures of postural balance and impact of visual spatial perception is important.

D.2. Phase 2 Results and Discussion

Descriptive statistics for the demographics of subjects that participated in Phase 2 are shown in Table 12.

Table 12. Demographics for Phase 2 subjects by experience.

	Inexperienced	**Experienced**
N	24	26
Age (years) ± s.d.	38.1 ± 9.4	40.5 ± 10.3
Height (cm)± s.d.	171.8 ± 9.2	171.4 ± 8.9
Weight (kg) ± s.d.	84.5 ± 17.2	87.7 ± 18.6
Gender	11 F and 13 M	2 F and 24 M

Separate repeat measure analyses of covariance (ANCOVA) were performed for each of ten postural sway outcome measurements. Three work experience variables: a dichotomous variable denoting work experience on inclined and/or elevated surfaces; a continuous variable representing the number of years of such work experience; and a continuous variable for the number of hours of such work activities during the week the worker was tested were treated as between subject factors in separate ANCOVAs. Three fatigue loading variables were analyzed as within subject factors in separate ANCOVAs: the fatiguing task that the worker performed during each trial, a trichotomous variable; the continuous Borg scale rated by the worker after each fatigue trial; and the continuous Bishop scale rated by each worker at each fatigue trial. Thus, a total of nine models representing each of the combinations of the 3 experience and 3 fatgue loading variables were run for each of the ten sway outcomes. In each of these analyses, the experimental conditions of task performed (reach vs. stationary) and inclination angle were treated as within subject variables and between subject covariates (e.g., age, gender, height) were analyzed for statistical significance. Covariates that were not significant at the $p < 0.05$ level were removed from the statistical models in a backward elimination process. The work experience, fatigue load and experimental condition variables were forced into each of the ANCOVA models and their statistical significance evaluated in the final models that included only statistically significant covariates.

The p-values from the ANCOVA models for the effects of work experience, fatigue load and the experimental conditions on each of the postural sway outcomes are shown in Table 13. Since multiple models were run for each of these factors (3 each for the work experience and loading variables and 9 each for the experimental conditions), the range of the p-values from these models is tabled. The range of p-values was generally quite small, and in no case did the multiple models analyzed for each of these factors differ in terms of their statistical significance on any of the sway outcomes. One-tail p-values are shown for the dichotomous factors of work experience and task and the continuous predictors of the sway outcomes (i.e., years of work experience, hours of work activity, and the Borg and Bishop scales). Two-tail p-values are shown otherwise (i.e., for the trichotomous factors of the fatiguing task performed and the inclination factor). The least square means (geometric means for sway area and length; arithmetic for the other 8 sway outcomes) for each of the categorical factors are shown in Table 14. The median least square mean from the multiple models analyzed is shown.

Experience was not found to influence postural sway, with the exception of the maximum H/V outcome. For this postural sway outcome, the number of years of work experience was found to be statistically significant in all 3 models run ($p<0.003$) and the dichotomous experience factor was marginally significant ($p=0.06$, all models). Experienced workers tended to have greater maximum H/V, 0.75 vs. 0.39 for inexperienced workers, or approximately 93% greater H/V (Table 14). The fatigue load also was generally not related to the postural sway outcomes. The only significant relationship was between the Borg scale and the FX outcome ($p<0.03$); the relationship of the Bishop scale to this outcome was marginally significant ($p=0.09$), while the fatiguing task performed was not ($p>0.62$). The task and inclination factors were significantly related to most of the postural sway outcomes; task was significant for 7 of the 10 outcomes and inclination was significant for 8 of the 10 sway variables. The magnitude of the effects for these two experimental conditions also was much larger than those determined for the experience and load factors, particularly for the primary sway outcomes of sway length and area. The reach task caused sway length to increase by 63% and sway area to increase by 204%; the 14 degree inclination increased both sway length and area by 19% relative to standing on a flat surface, while the 26 degree inclination caused sway length to increase by 55% and sway area to increase by 38% relative to standing on a flat surface (Table 14).

Table 13. Range of P-values for testing the effects of experience, load, task and inclination on the sway parameters (n=50).

Experimental Condition or Factor	Length	Area	ML	AP	Max. ML	Max. AP	FX	FY	Min. HV	Max. HV
Work Experience Variables:										
Experienced vs. Inexperienced	0.99	0.97	0.95	0.95	0.94 - 0.95	0.96	0.35 - 0.44	0.77 - 0.78	0.97 - 0.98	0.06
Years of Work Experience	0.97	0.91 - 0.92	0.99	0.79 - 0.80	0.99	0.81 - 0.92	0.38 - 0.40	0.64 - 0.66	0.86 - 0.87	**0.003**
Hours of Work Activity	0.97	0.82 - 0.83	0.67 - 0.69	0.63 - 0.65	0.67 - 0.69	0.90	0.51- 0.54	0.78- 0.80	0.98	0.36 - 0.39
Load Variables:										
Fatiguing Task Performed (Full vs. Half vs. None)	0.94 - 0.95	0.24 - 0.27	0.99	0.49	0.99	0.60 - 0.69	0.62 - 0.68	0.30 - 0.33	0.87	0.86
Borg Scale	0.25 - 0.32	0.47 - 0.48	0.49 - 0.52	0.14 - 0.16	0.49 - 0.52	0.28 - 0.38	**0.03**	0.91 - 0.93	0.20 - 0.21	0.39 - 0.41
Bishop Scale	0.45 - 0.49	0.62	0.69 - 0.74	0.34 - 0.39	0.70 - 0.74	0.60 - 0.65	0.09	0.89 - 0.91	0.17 - 0.19	0.20 - 0.23
Experimental Conditions:										
Task (Reach vs. Stationary)	**0.0001**	**0.0001**	0.30 - 0.33	**0.0001**	0.20 - 0.23	**0.0001**	**0.0001**	**0.0001**	**0.0001**	0.31 - 0.42
Inclination (0 vs. 14 vs. 26 degrees)	**0.0001**	**0.0001**	**0.04 - 0.05**	0.30 - 0.32	**0.05**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	0.07 - 0.08

Table 14. Median Least Square Means calculated from repeat measure ANCOVA models for testing the effects of experience, load, task and inclination on the sway parameters (n=50).

Experimental Condition or Independent Variable	Geometric Mean Length	Geometric Mean Area	ML	AP	Max. ML	Max. AP	FX	FY	Min. HV	Max. HV
Experience:										
Inexperienced	81.614	8.568	11.347	6.387	9.687	2.056	210.47	256.74	0.0019	0.3871
Experienced	90.649	9.043	26.719	7.040	24.039	2.870	210.00	267.08	0.0019	0.7483
Load:										
Full	85.541	8.466	18.247	6.860	16.133	2.489	206.10	259.14	0.0019	0.6095
Half	86.488	8.750	19.731	6.515	17.621	2.229	206.65	258.08	0.0019	0.4230
None	86.747	8.998	19.068	6.607	16.800	2.573	209.96	263.85	0.0019	0.6677
Task:										
Reach	109.727	15.226	25.243	8.127	23.033	4.351	217.13	284.04	0.0010	0.5044
Stationary	67.491	5.013	13.425	5.191	10.697	0.485	198.07	235.81	0.0028	0.6211
Inclination:										
0 degrees	70.246	7.404	4.827	6.434	2.781	3.279	201.53	276.35	0.0024	0.2392
14 degrees	83.429	8.776	6.276	6.585	4.001	1.930	214.17	255.80	0.0019	0.2629
26 degrees	108.744	10.268	45.990	6.961	43.808	2.082	207.10	249.27	0.0014	1.2031

D.2.1. Phase 2 ISCAN Results and Discussion: Cue placement

Descriptive statistics for the number of data points intersecting a plane demonstrated that the plane in the center of the wall is looked at most of the time with the planes directly above and below the center also being looked at frequently. Figure 26 displays the mean number of hits for each plane defined. A regression analysis using a general linear model was used to determine the within subject effect of incline, load, task, and all of the 2 way interactions of them. For planes 1 and 6, which are located in the center of the front wall directly in front of the subject, the task was significant with the stationary task having more "hits" in these planes than the reach task. For planes 9 and 10, which are located on the front wall close to the floor, the task and incline were significant with the reach task and higher inclines receiving more "hits". Table 15 shows the parameter estimates and p values for each significant variable for each plane.

Table 15. Phase 2 ISCAN data parameter estimates and p-values for significant variables for each plane. For planes 0, 2, 3, 4, 5, 7, 8, 11, and 12, the incline, load task and all the two-way interactions were not significant.

Plane	Variable	p-value
1	Task	0.02
6	Task	0.05
9	Task	0.03
	Incline*load	0.02
10	Incline	0.05
	Task	0.02

Figure 26. The mean and standard deviations for the number of visual "hits" for each plane for Phase 2.

Plane 2: 0.69 ± 6.45	Plane 3: 191.34 ± 394.24	Plane 4: 1.64 ±11.09
Plane 5: 2.16 ± 11.65	Plane 1: 570.32 ± 553.10 Plane 6: 618.10 ± 510.72	Plane 7: 7.38 ± 33.96
Plane 8: 0.91 ± 5.41	Plane 9: 100.91 ± 196.56	Plane 10: 2.48 ± 9.87
Plane 11: 4.12 ± 23.17 (floor)		Plane 12: 6.59 ± 29.41 (floor)

Plane 0 (did not intersect any defined planes): 3.77 ± 30.81

Visual Cue pilot test:
From these results, a pilot test was carried out to determine the most effective region for visual cue placement for Phase 3. From a previous study conducted in the laboratory [45], it was found that a visual cue with one horizontal line and two vertical lines on each end of the horizontal line, or an H-shaped cue, aided in postural stability. Since the preliminary results of the Phase 2 ISCAN data demonstrated subjects looked primarily in the center of the front panel, a cue with one horizontal and one vertical line, or a cross-shaped cue, needed to be investigated further. A pilot test was conducted to determine if a difference in postural balance could be detected using the H- or cross- shaped cues (see figure 27). Each piece (rectangle) of the cue measures 104.5 inches by 3 inches. It was expected that with the appropriate visual cue, postural sway will decrease (i.e. improve postural balance).

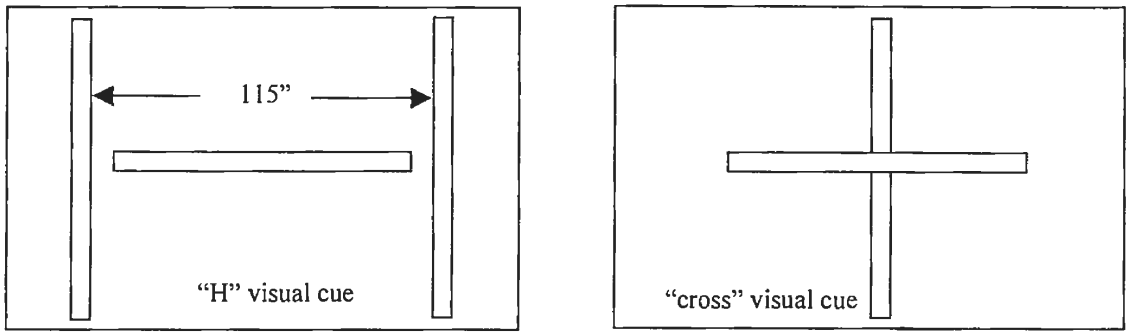


Figure 27. Visual cues used in pilot experiment

Testing Protocol: Five male subjects were tested using an AMTI force platform mounted with or without a 26 degree inclination. Each subjects performed six trials, with two inclines (0°and 26°) and two visual cues (H and cross). These four trials were randomized by incline within subject using SAS randomization procedure. The subjects wore a safety harness while performing all trials. Each trial lasted 30 seconds that involved the subjects standing quietly on the force platform looking forward. The raw data were processed using the custom "Kinelysis" software to calculate postural sway variables (sway length and area). The sway data were then analyzed with SAS General Linear Model (SAS GLM) procedure.

Visual Cue pilot results: Results from SAS GLM showed that there is a significant difference in postural sway between two inclinations ($p<0.0002$ for sway length and $p<0.032$ for sway area). However, cue placement as well as interaction between cue and incline was not significant in the GLM. The results are summarized in Tables 16 and 17. Based upon the preliminary results implying better postural balance, the H-shaped cue had the lowest sway length and area. From these results, it was decided the H-shaped cue would be used for Experiment 3 testing.

Table 14. Sway data for two inclinations for visual cue pilot

Incline	Sway Length (cm)		Sway Area (cm^2)	
	Mean	S.D.	Mean	S.D.
0 degree incline	30.90	4.82	2.13	2.04
26 degree incline	59.47	9.98	4.52	1.79

Table 15. Sway data for different visual cue placements for visual cue pilot

Visual Cue	Sway Length (cm)		Sway Area (cm^2)	
	Mean	S.D.	Mean	S.D.
No cue	45.85	18.00	3.88	2.58
H-shaped	40.56	15.24	2.49	1.54
Cross-shaped	45.89	16.94	3.29	2.46

D.2.2. Before or After Work Testing

To determine if testing subjects before or after their regular workday affected the results of the study, five subjects repeated a single test session (10 trials) opposite of the time they completed the first session. For example, if they came to the first test session before they went to their regular work for that day, the repeated session was scheduled after their regular workday on another day. The postural balance parameters of sway area and length and excursion in the ML and AP direction were used in the analysis. A t-test of the difference between the test session after work and the test session before work (after-before) was completed. The difference between the before and after for sway length and the AP excursion was significant ($p<0.05$) showing a mean difference of –0.084 and –0.083 for SL and AP Excursion respectively. The negative mean values indicate that the subjects had better postural balance in the after work session. In addition, variables such as the overall perceived exertion and overall discomfort that were self-reported on the day of the visit were used. None of these variables showed a difference between before and after work. Because of these findings, we decided to test the subjects at their convenience and not only before their regular workday.

D.3. Phase 3 Results and Discussion

For all statistical analysis models, the main effects of load, task, incline and cue were included with the following covariates shown in table 18. Additional covariates of eye vision were included in the Eye movement analysis and are described in Appendix J.

Table 18. Covariates used in statistical analyses for Phase 3.

The following data was collected ***one time*** for each subject:

Variable	Units	Description	Range	Questionnaire
ALC_NUM_MON	Drinks/ month	Average number of alcoholic drinks consumed per month	continuous	Preliminary Questionnaire mailed to subjects: On average, how often did you drink alcohol? (daily, weekly or monthly) and # (all responses were converted to monthly)
CAFF_D	Drinks/da y	Average number of caffeinated drinks consumed per day	continuous	Preliminary Questionnaire mailed to subjects: # caffeinated drinks per day?
CIGS_D	Cigs/day	Average number of cigarettes smoked per day	continuous	Preliminary Questionnaire mailed to subjects: # cigs smoked per day?
AGE	Years	age	continuous	Anthropometry
BMI	Kg/m^2	Body mass index	continuous	Anthropometry
MALE	0 or 1	gender	dichotomous	Anthropometry
BLACK	0 or 1	race	dichotomous	Anthropometry
MUSCLE_H_AVG	Lbs.	Strength of L and R hams	continuous	VMAX, load cell data
MUSCLE_Q_AVG	Lbs.	Strength of L and R quads	continuous	VMAX, load cell data
MUSCLE_T_AVG	Lbs.	Strength of L and R tibs	continuous	VMAX, load cell data
MUSCLE_G_AVG	Lbs.	Strength of L and R gas	continuous	VMAX, load cell data
ARMREACTION	Sec.	Rxn time of dominant arm	continuous	Anthropometry
FOOTREACTION	Sec.	Rxn time of dominant foot	continuous	Anthropometry

The following data was collected ***each session*** for each subject:

Variable	Units	Description	Range	Questionnaire
HRS_WRK	Hours	# hours worked in the last 12 hours	0-12	Self Reported Evaluation Checklist, Q3
SHFT_CHG	0(no) or 1(yes)	Did the subject change shifts in the last week	dichotomous	Self Reported Evaluation Checklist, Q4
ELEV_HR	Hours	# hours worked on an elevated surface in the last twelve hours	0-12	Self Reported Evaluation Checklist, Q5
INC_HR	Hours	# hours worked on an inclined surface in the last twelve hours	0-12	Self Reported Evaluation Checklist, Q6
OV_ALLPE	PE	Overall perceived exertion for the last twelve hours	6-20	Self Reported Evaluation Checklist, Q7 (6 is very, very light and 20 is very, very hard)
OV_ALDIS	DIS	Overall discomfort in last twelve hours	0-63	Self Reported Evaluation Checklist, Q8 (21 body parts were ranked from 0, no discomfort to 3, extremely uncomfortable and summed)
HRS_SLPT	hours	Hours slept night before session	0-24	Session interview, Q1
HRS_LMEAL	hours	Hours since last meal	continuous	Session interview, Q3
CAFFEINE	ounces	Ounces of caffeinated beverage consumed in last twelve hours	continuous	Session interview, Q4
CIG_NUM	#cigs	# of cigarettes in last 12 hours	continuous	Session interview, Q5
FALL_JOB	0 or 1	Has the subject fallen on the job since the last visit	dichotomous	Session interview, Q11
STRENACT	0 or 1	Anything strenuous in the last 24 hours	dichotomous	Session interview, Q12
STRESSFUL	0 or 1	Anything stressful at home or on the job in the last 24 hours	dichotomous	Session interview, Q13

A t-test was completed to compare the experienced and inexperienced subjects in Phase 3. Descriptive statistics for the demographic information for Phase 3 test subjects and the t-test p-values are shown in the following tables. Table 19 shows the demographics by experience level. Table 20 shows the descriptive statistics for the significant continuous covariates and table 21 shows the categorical covariates. Table 22 shows variables that were averaged over all sessions since they were obtained for each test session. Finally, table 23 shows the descriptive statistics for the variables, which were not significant in the t-test.

Table 19. Phase 3 demographic information by experience

	Non-Experienced	Experienced	2 Tailed P-value
N:	26	22	
age :			0.17
MEAN	37.6	41.6	
STD	10.3	9.64	
MIN	20.9	26.6	
MAX	55.1	58.8	
bmi :			0.78
MEAN	28.8	28.4	
STD	4.74	4.80	
MIN	20.9	20.5	
MAX	38.7	37.9	
Height :			0.70
MEAN	171.9	172.9	
STD	9.28	8.71	
MIN	155	155.8	
MAX	188.3	188.4	
Weight :			0.90
MEAN	85.6	85.0	
STD	17.7	15.2	
MIN	50.6	58.4	
MAX	120	111.8	

Table 20. Significant Continuous Covariates from t-test.

	Non-Experienced	Experienced	2 Tailed P-values
Exp_job :			<0.0001
MEAN	0.46	117	
STD	2.35	96.6	
MIN	0	0	
MAX	12	360	
Activity :			<0.0001
MEAN	0.61	27.2	
STD	3.14	11.8	
MIN	0	0	
MAX	16	50	
Alc_num:			0.03
MEAN	6.79	15.3	
STD	12.4	13.2	
MIN	0	0	
MAX	60	45	
Caff_d :			0.001
MEAN	1.27	2.59	
STD	0.99	1.60	
MIN	0	0	
MAX	3	5	
Muscle_t_avg :			0.002
MEAN	28.7	38.8	
STD	8.42	13.9	
MIN	18.4	12.7	
MAX	50.6	75.3	
Muscle_q_avg :			0.002
MEAN	38.3	53.8	
STD	13.9	19.4	
MIN	15.7	28.9	
MAX	70.2	116.4	
Muscle_g_avg :			0.0008
MEAN	42.9	63.7	
STD	17.7	22.5	
MIN	22.5	31.7	
MAX	89.3	107.2	
Muscle_h_avg :			0.02
MEAN	13.4	18.7	
STD	6.57	8.32	
MIN	3.54	5.98	
MAX	29.5	36.7	

Table 21. Categorical covariates from t-test

	Non-Experienced	Experienced	2 Tailed P-values
Gender: total	26	22	0.8996
Female (%)	9 (34.62)	8 (36.36)	
Race: total	26	22	1
Black (%)	13 (50)	11 (50)	
Caffeine: total	123	101	0.0061
Yes (%)	48 (39.02)	58 (57.43)	
Fall_job: total	123	101	0.2687
Yes (%)	0 (0)	1 (0.99)	
Strenact: total	123	101	0.4985
Yes (%)	8 (6.50)	9 (8.91)	
Stressful: total	123	101	0.7407
Yes (%)	6 (4.88)	4 (3.96)	
Shft_chg: total	123	101	0.2687
Yes (%)	0 (0)	1 (0.99)	
Contacts: total	24	21	0.3442
Yes (%)	1 (4.17)	0 (0)	
Glasses: total	18	11	0.1488
Yes (%)	8 (44.44)	2 (18.18)	

Table 22. Covariates that were averaged over session for t-test.

	Non-Experienced	Experienced	2 Tailed P-values
Ov_allpe :			0.11
MEAN	9.17	10.1	
STD	1.79	2.47	
MIN	5	6	
MAX	13	16	
Hrs_wrk :			0.08
MEAN	2.54	4.22	
STD	3.12	3.44	
MIN	0	0	
MAX	9	8.25	
Elev_hr :			**0.01**
MEAN	0.07	1.37	
STD	0.34	2.19	
MIN	0	0	
MAX	1.75	7.88	
Inc_hr :			0.06
MEAN	0	0.27	
STD	0	0.62	
MIN	0	0	
MAX	0	2.69	
Hrs_lmeal :			0.22
MEAN	5.72	4.42	
STD	3.95	3.09	
MIN	0.52	1.2	
MAX	12.88	12.75	
Cig_num :			**0.05**
MEAN	0.51	1.91	
STD	0.60	3.20	
MIN	0	0	
MAX	2	11.25	
Hrs_slpt :			0.32
MEAN	7.27	6.97	
STD	1.05	1.01	
MIN	5.5	5.38	
MAX	10.4	9.63	
Ov_aldis:			0.50
MEAN	1.72	3.71	
STD	3.71	11.9	
MIN	0	0	
MAX	15	55.8	

Table 23. Non-significant covariates from t-test

	Non-Experienced	Experienced	2 Tailed P-values
BF2 :			0.702
MEAN ± S.D.	9.42 ±2.83	9.73 ±2.64	
BN9 :			0.786
MEAN ± S.D.	8.96 ±3.67	8.64 ±4.27	
LATF8 :			0.401
MEAN ± S.D.	9.46 ±2.43	8.71 ±3.42	
LATN12 :			0.748
MEAN ± S.D.	8.67 ±3.10	8.33 ±3.80	
LF4 :			0.819
MEAN ± S.D.	8.04 ±3.19	8.27 ±3.61	
LN11 :			0.480
MEAN ± S.D.	8.17 ±3.63	7.41 ±3.57	
RF3 :			0.505
MEAN ± S.D.	7.42 ±3.30	8 ±2.49	
RN10 :			0.676
MEAN ± S.D.	8 ±3.57	8.45 ±3.58	
SD5 :			0.901
MEAN ± S.D.	5.17 ±3.08	5.3 ±3.53	
VERF7 :			0.280
MEAN ± S.D.	3.79 ±1.10	3.33 ±1.68	
ARMREACTION :			0.530
MEAN ± S.D.	36.3 ±8.00	35.0 ±6.23	
FOOTREACTION :			0.354
MEAN ± S.D.	41.5 ±7.19	39.7 ±5.78	
EXERTION :			0.519
MEAN ± S.D.	3.94 ±1.75	4.27 ±1.82	
DISCOMFORT :			0.474
MEAN ± S.D.	4.26 ±2.84	4.89 ±3.22	
LF4 :			0.819
MEAN ± S.D.	8.04 ±3.19	8.27 ±3.61	
LN11 :			0.480
MEAN ± S.D.	8.17 ±3.63	7.41 ±3.57	
RF3 :			0.505
MEAN ± S.D.	7.42 ±3.30	8 ± 2.49	
RN10 :			0.676
MEAN ± S.D.	8 ±3.57	8.45 ±3.58	
SD5 :			0.901
MEAN ± S.D.	5.17 ±3.08	5.3 ±3.53	

D.3.1. Description of the temporal kinematic, kinetic and EMG patterns of an experienced and inexperienced worker in two extreme test conditions

The two extreme test conditions included the best and the worst-case scenarios on each incline among the 12 combinations of the test conditions (2 tasks × 2 visual cue settings × 3 levels of fatigue). The best condition was a stationary task with visual cues and without fatigue; the worst condition was a reach task without visual cues and with full fatigue. Figures 28-33 and 34-39 show the kinematic and kinetic parameters of an experienced and an inexperienced worker on the three inclinations for the best and the worst test conditions, respectively. Figures 40-51 show the EMG activity patterns of the 8 lower limb muscles for the worst test condition on each incline. Since the EMG activity patterns of the muscles for the best test condition were similar to those before (baseline) performing the reach task in the worst test condition, they are discussed with the worst test condition.

Description of the event numbers:

The event numbers 1-4 in the Figures correspond to the beginning of the reach task (hands off the hips, event #1), hands on the weight (event #2), hands off the weight (event #3) and hands back on the hips (the end of the reach task, event #4).

Temporal kinematic and kinetic patterns of the best and worst case test conditions for an experienced and an inexperienced worker

Hip, elbow and shoulder angles of an experienced and an inexperience workers for the best test condition on the inclinations: Hip, elbow and shoulder angles for the stationary task on the three inclinations for an experienced and an inexperienced workers are shown in Figures 28 and 29, respectively. For the experienced worker, hip, elbow and shoulder angles on the 0° inclination were maintained approximately at 172°, 90°, and 54°, respectively. The elbow and shoulder angles on the 14° and 26° inclinations were approximately the same , -90° and 50° for the elbow and shoulder, respectively. However, the hip angle decreased from 170° on the 14° inclination to approximately 164° on the 26° inclination. For the inexperienced worker, the elbow and shoulder angles have very similar patterns as the experienced worker except the hip angles on the 14° and 26° inclinations. The hip angles on the 14° and 26° inclinations were maintained at 164° and 171°, respectively. In summary, the most significant difference in the hip, elbow and shoulder angles between the experienced and inexperienced workers was the hip angles on the 14° and 26° inclinations.

Hip, elbow and shoulder angles of an experienced and an inexperience worker for the worst test condition on the inclinations: Figures 34 and 35 show the temporal patterns of hip, elbow and shoulder angles while performing the reach task on the three inclinations for the experienced and inexperienced workers. Compared with the patterns while standing on the inclinations, the experienced and inexperienced workers had the similar temporal patterns of hip, elbow and shoulder angles during the beginning of the reach task trial. Similar to the stationary task, the most significant difference in the hip, elbow and shoulder angles between the experienced and inexperienced workers was the hip angles on the 14° and 26° inclinations. For the experienced

worker on the 14° and 26° inclinations, hip angles were maintained at 176° and 162°, respectively and for the inexperienced worker, hip angle were maintained at 160° and 170°, respectively. During the reach task, the experienced worker appeared to use more hip movement to perform the task than the inexperienced worker. In summary, the experienced worker tended to flex his hip more than the inexperienced worker while performing the stationary and reach tasks.

Temporal changes in the body's CG and CP for an experienced and an inexperience worker for the best test condition on the inclinations: Figures 30 and 31 show that temporal changes in the body's CG and the CP for an experienced and an inexperience workers while standing on the inclinations. The CP and CG patterns for the experienced and inexperienced workers were similar. The ranges of the CP and CG movements were approximately 2 cm for both workers. The CP seemed to follow the CG throughout the trial. Figures 32 and 33 show similar responses for an experienced and an inexperienced subject for the placement of the CG with respect to the BOS as defined by the toe and heel markers.

Temporal changes in the body's CG and CP for an experienced and an inexperience workers for the worst test condition on the inclinations: Figures 36 and 37 show the temporal changes in the body's CG and CP for an experienced and an inexperience workers while performing the reach task on the inclinations. Similar to the relationship between the CG and the CP during the stationary task trial, the CP tended to follow the CG throughout the reach task trial. However, the CP moved in a greater distance during the reach task than the CG. Figures 38 and 39 show similar responses for an experienced and an inexperienced subject for the placement of the CG with respect to the BOS as defined by the toe and heel markers.

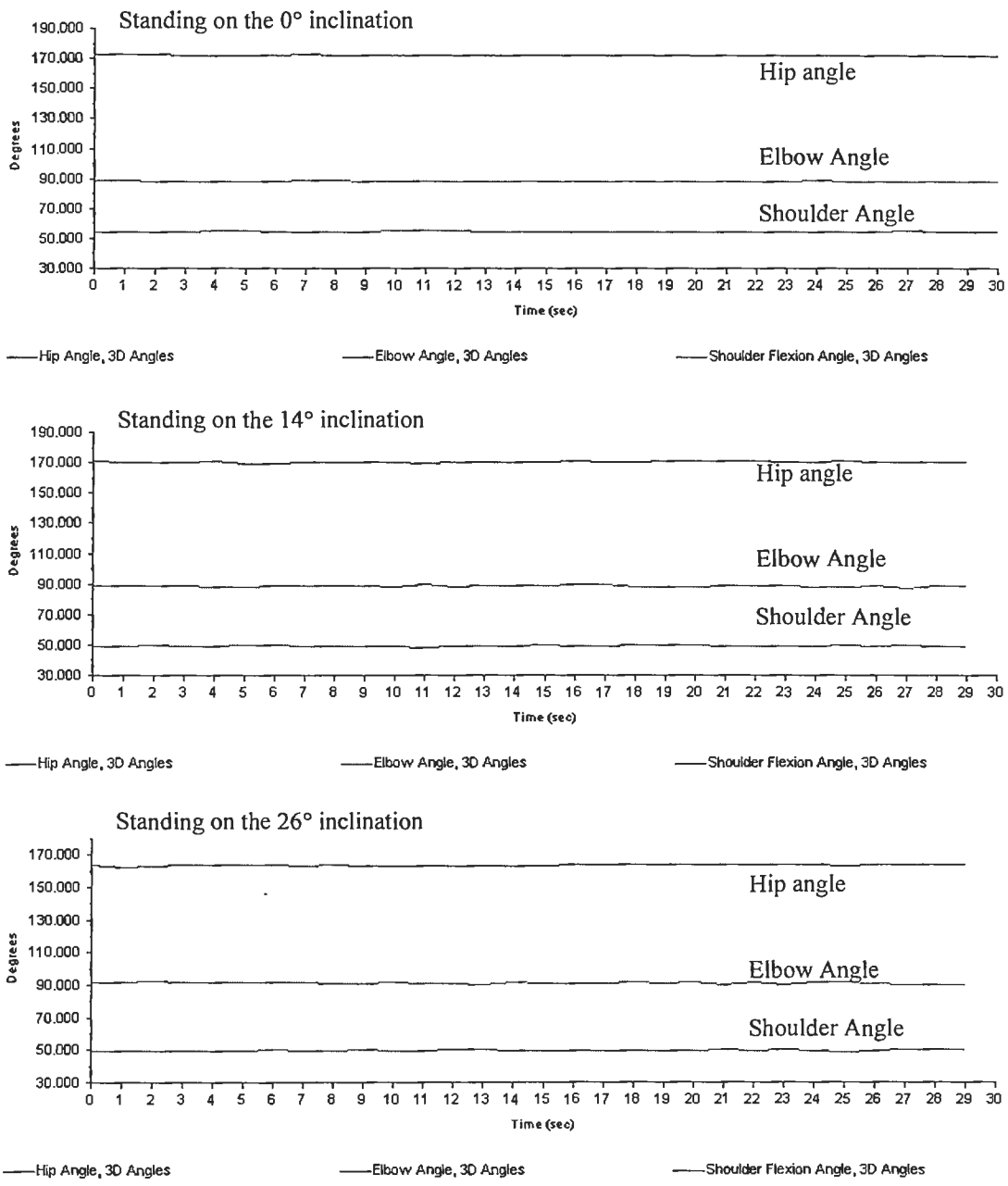


Figure 28. Temporal angle patterns of the shoulder, elbow and hip while standing on three different inclinations for an experienced subject

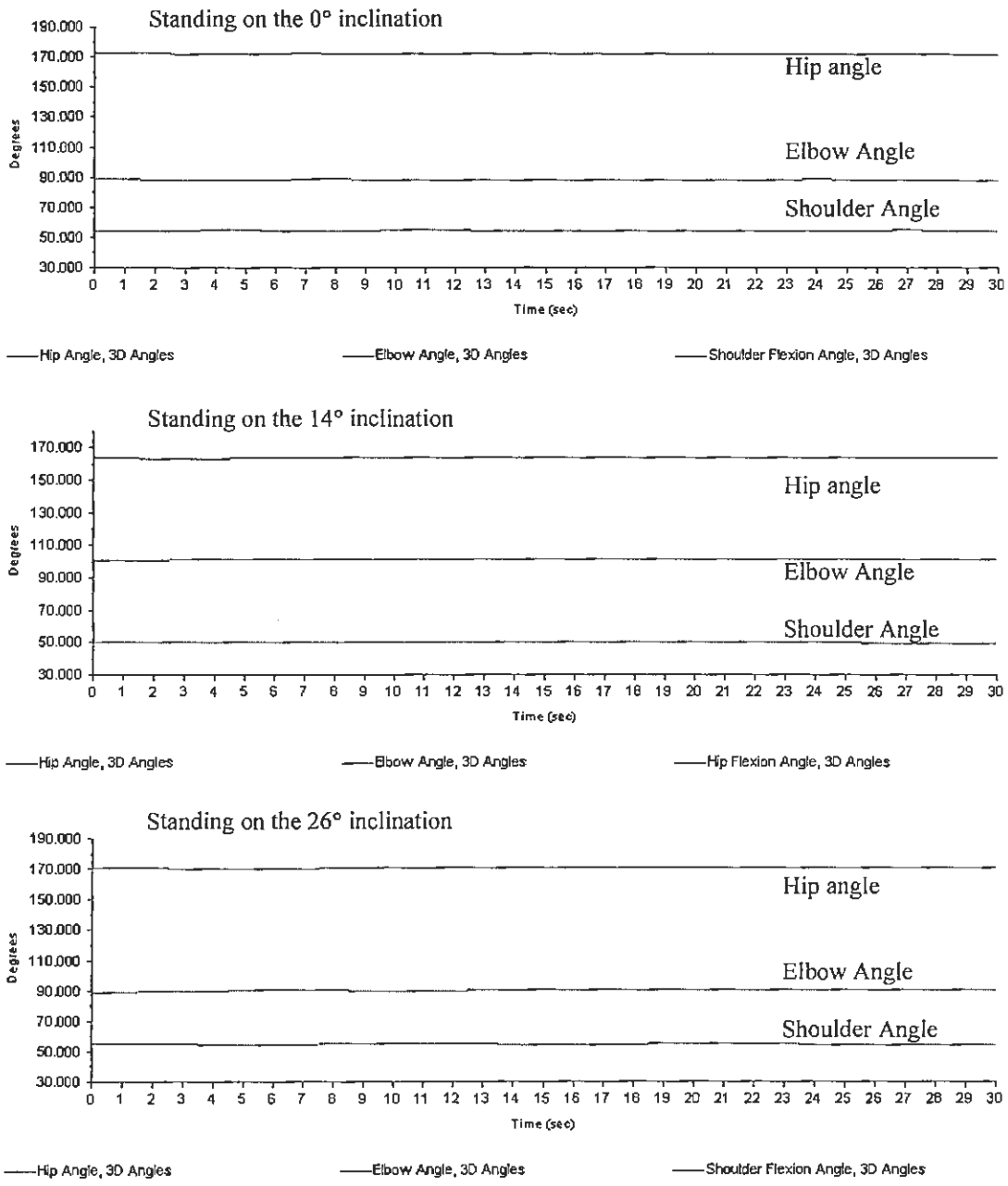
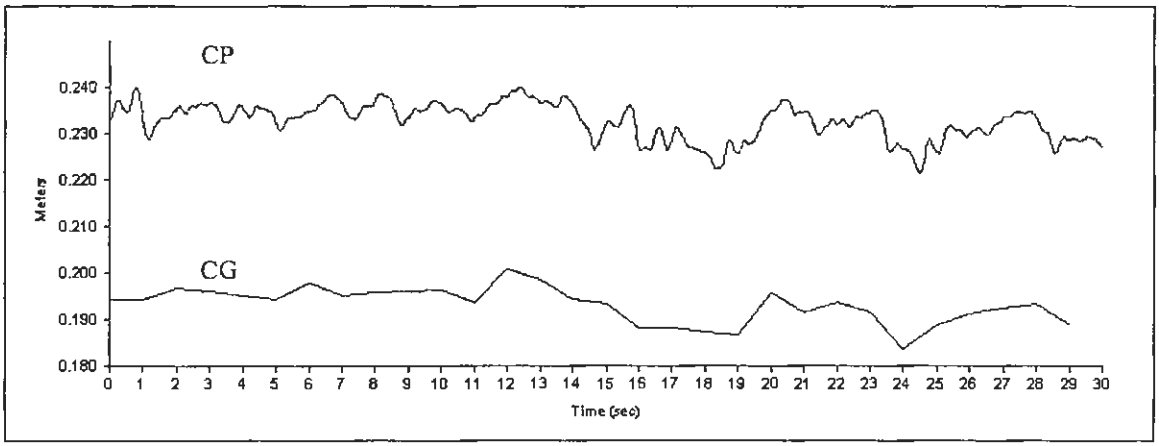
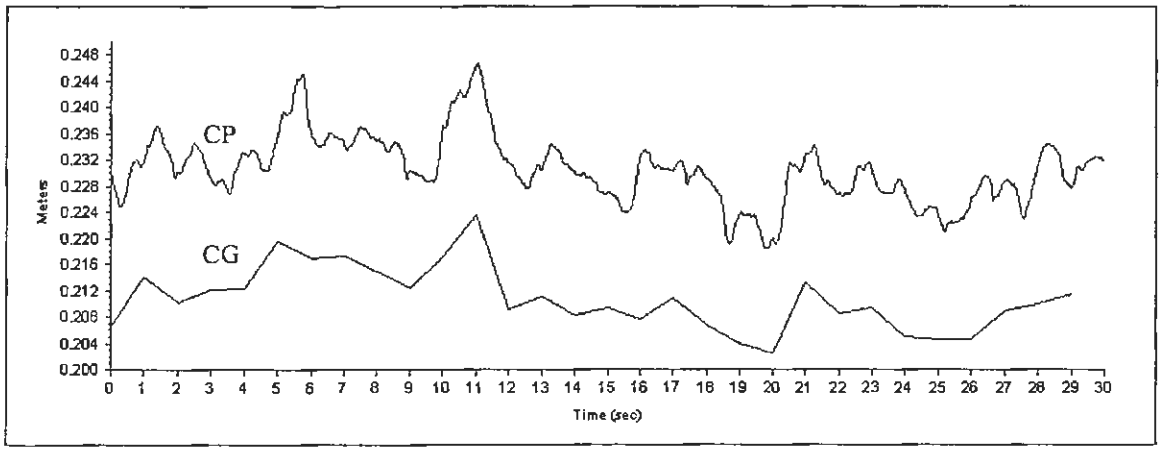


Figure 29. Temporal angle patterns of the shoulder, elbow and hip while standing on three different inclinations for an inexperienced subject

Standing on the 0° inclination



Standing on the 14° inclination



Standing on the 26° inclination

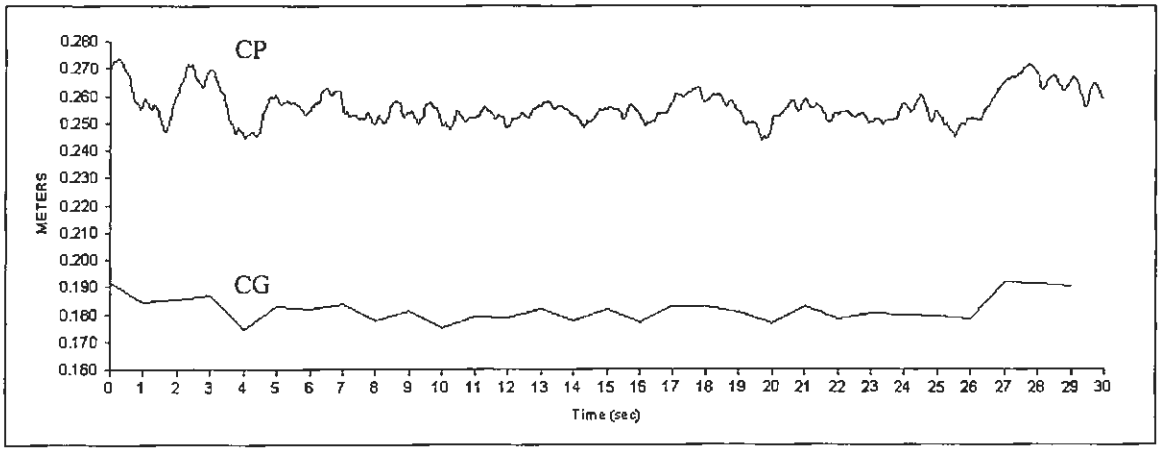
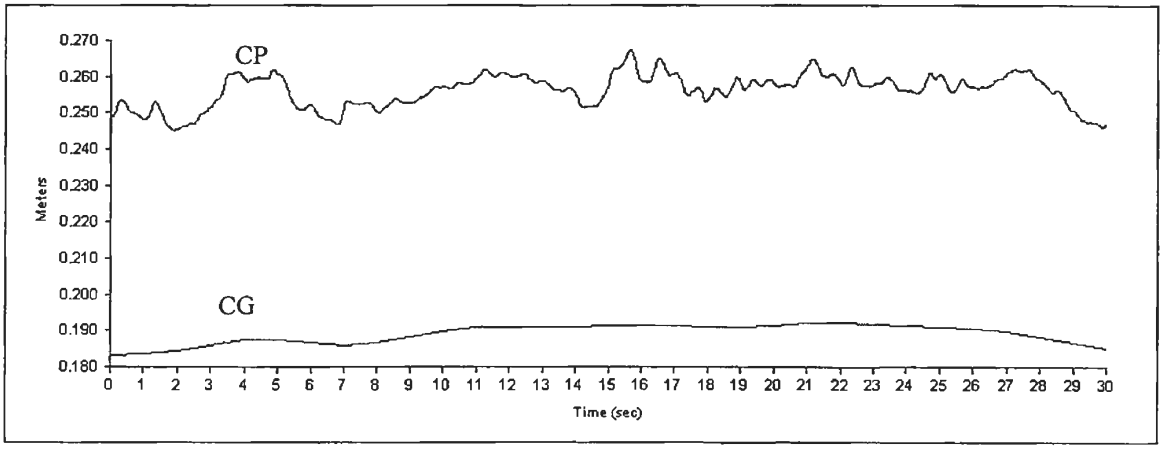
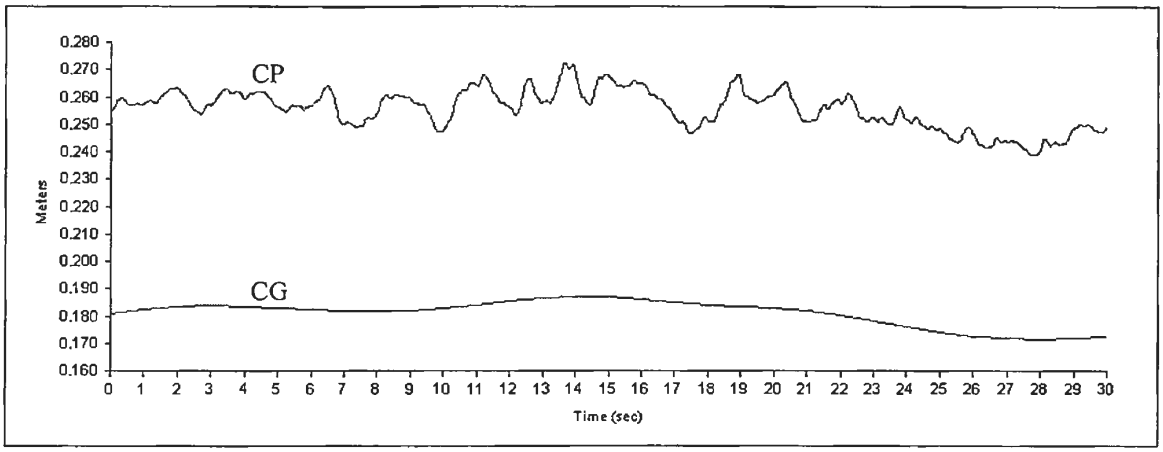


Figure 30. Temporal patterns of the CP and CG in the AP direction for an experienced subject

Standing on the 0° inclination



Standing on the 14° inclination



Standing on the 26° inclination

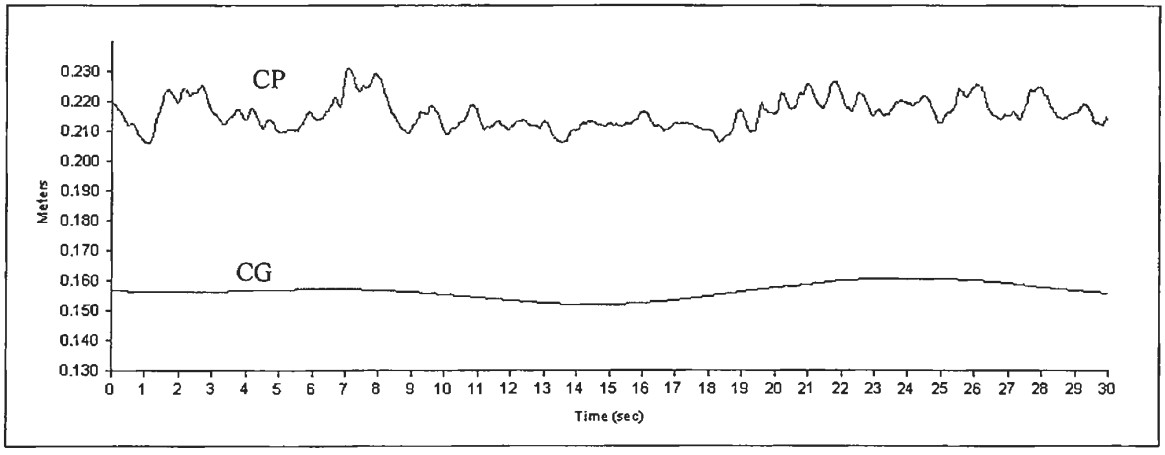


Figure 31. Temporal patterns of the CP and CG in the AP direction for an inexperienced subject

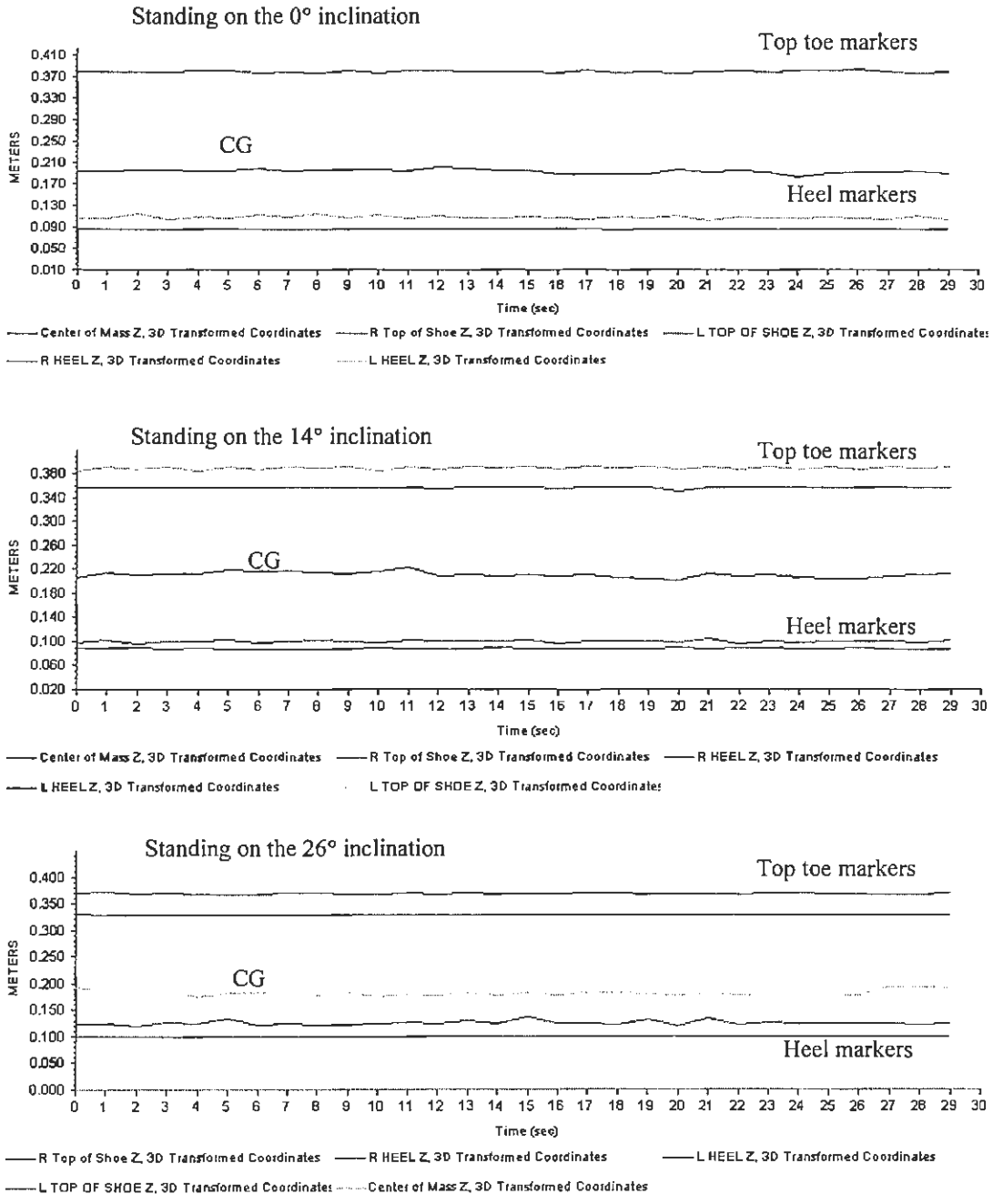


Figure 32. Temporal patterns of the CG with respect to the BOS in the AP direction for an experienced subject

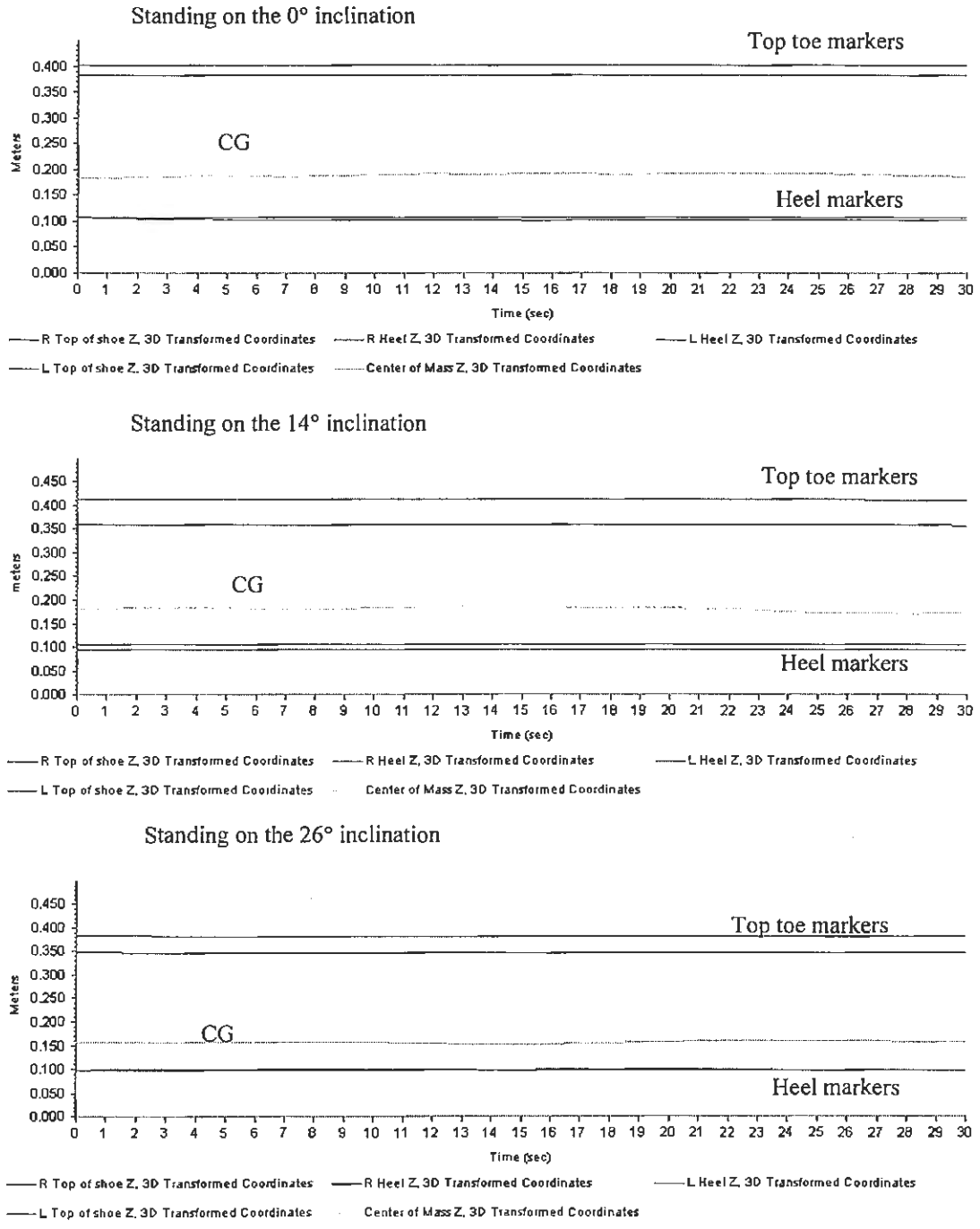


Figure 33. Temporal patterns of the CG with respect to the BOS in the AP direction for an inexperienced subject

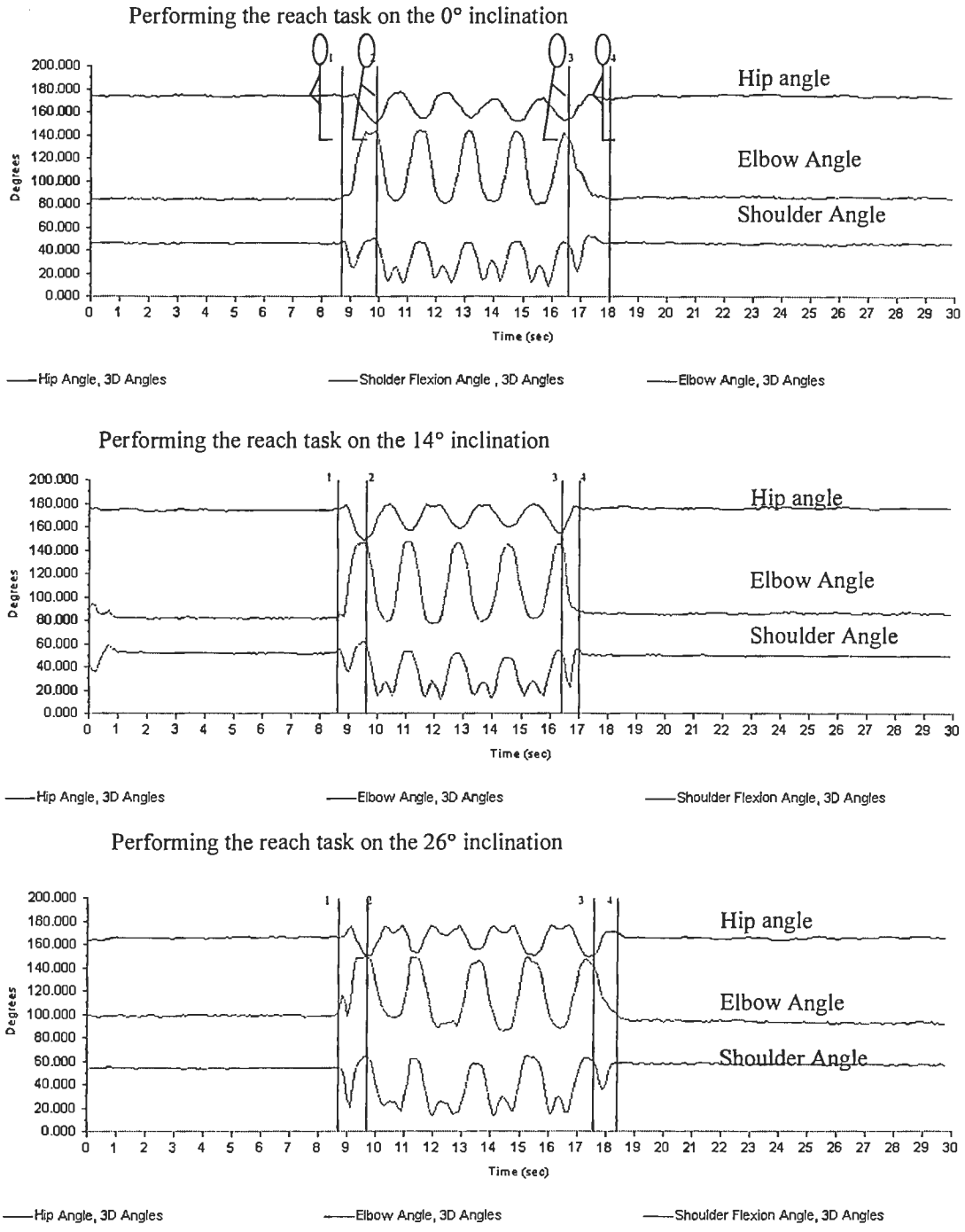


Figure 34. Temporal angle patterns of the shoulder, elbow and hip while performing the reach task on three different inclinations for an experienced subject

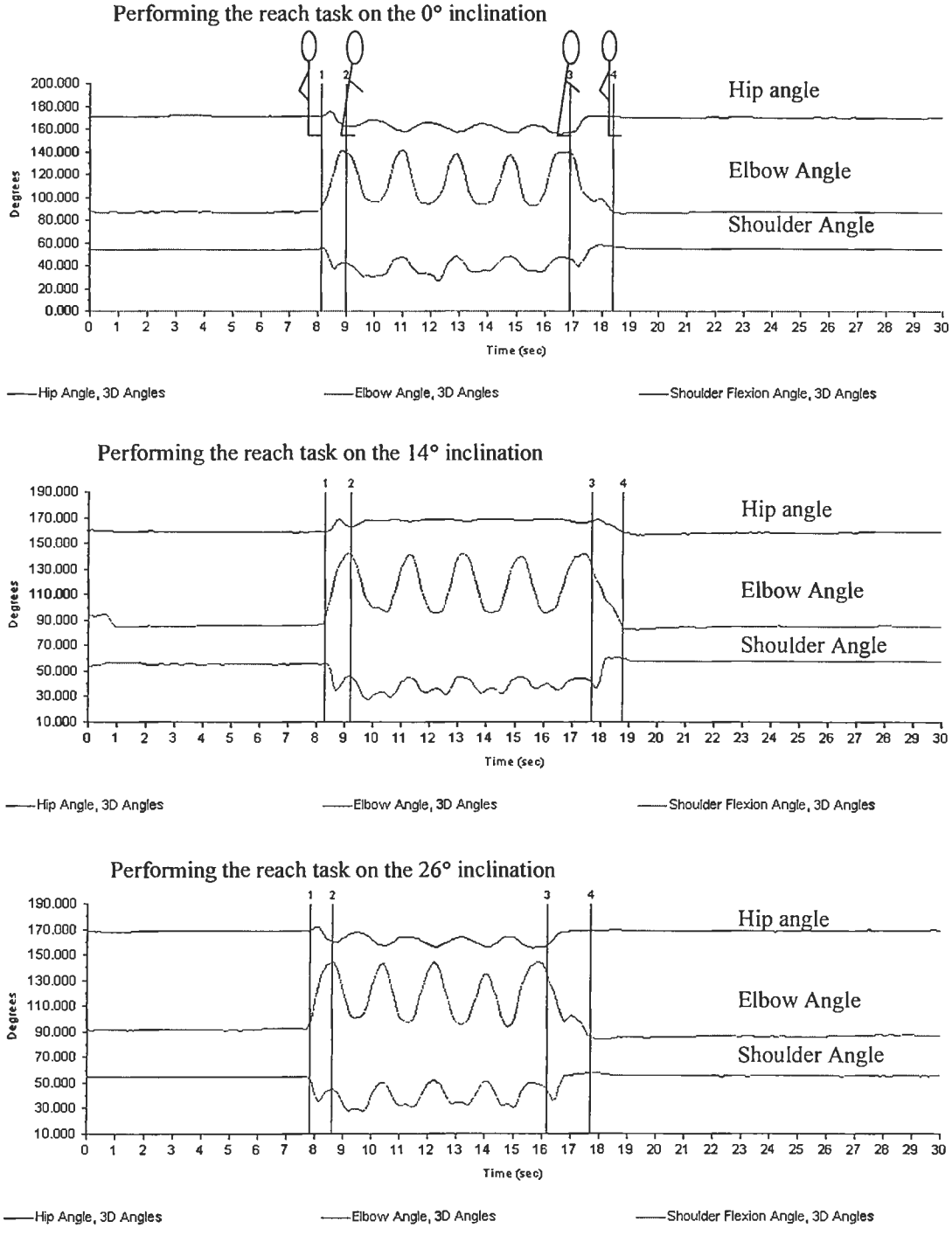
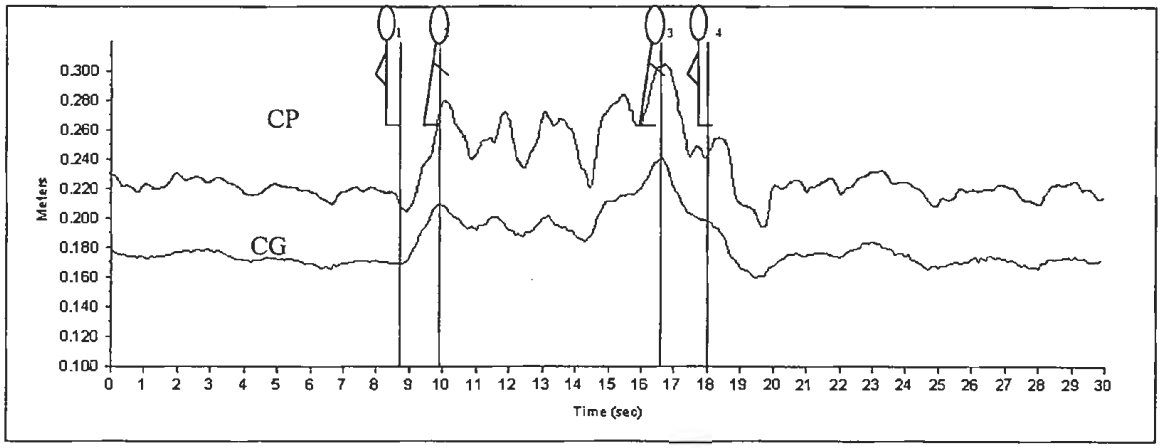
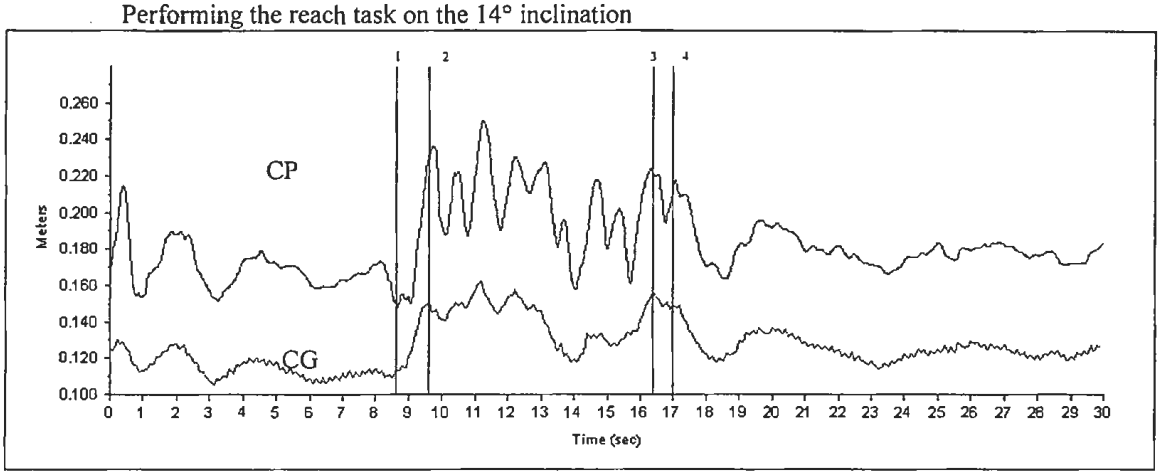


Figure 35. Temporal angle patterns of the shoulder, elbow and hip while performing the reach task on three different inclinations for an inexperienced subject

Performing the reach task on the 0° inclination



Performing the reach task on the 14° inclination



Performing the reach task on the 26° inclination

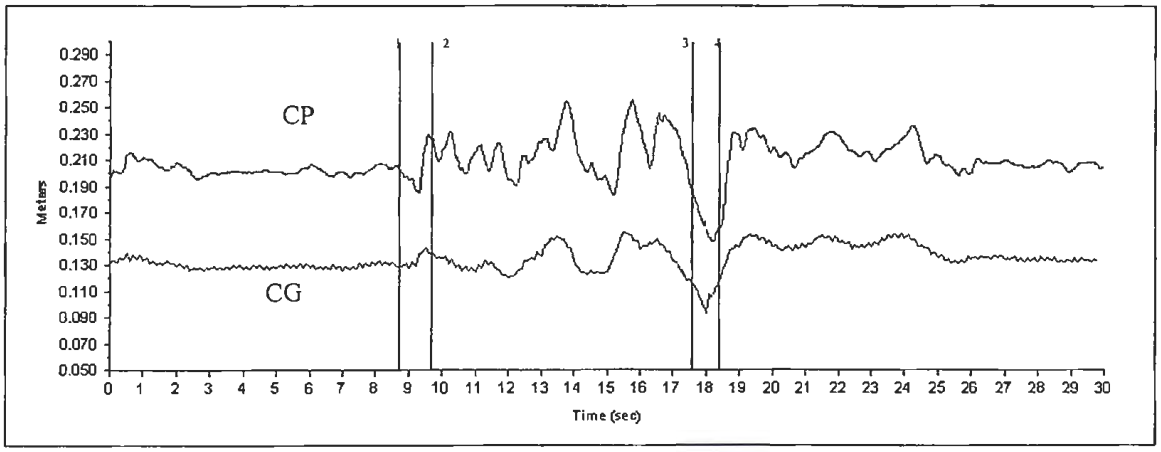
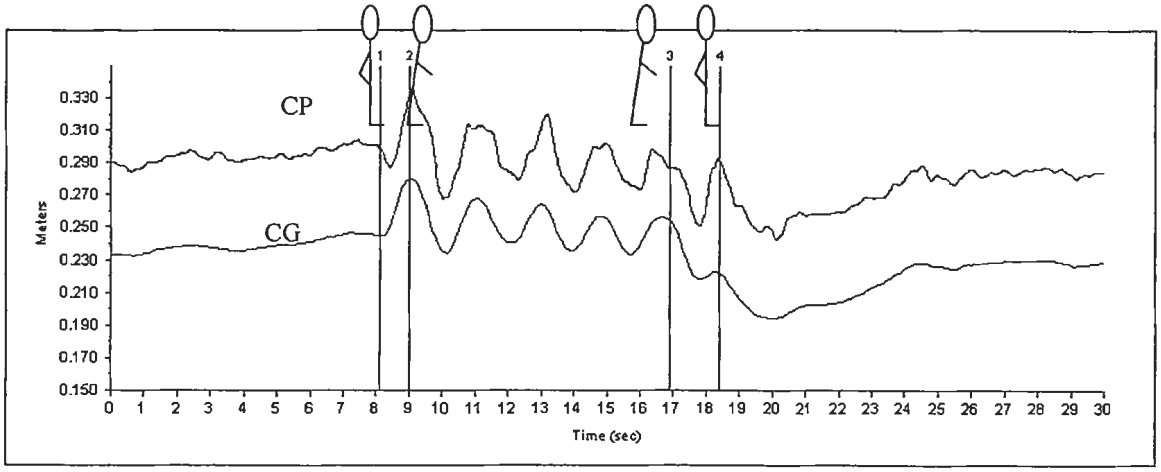
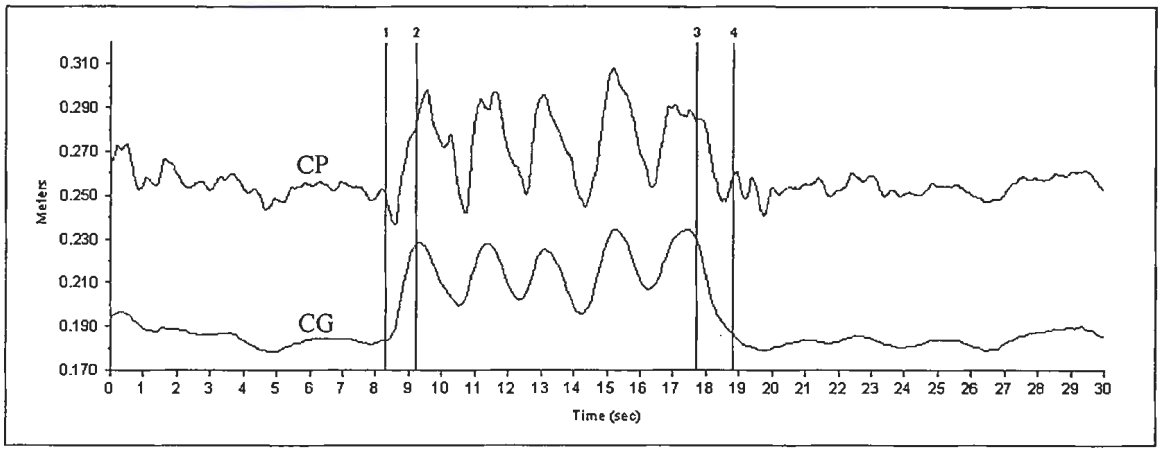


Figure 36. Temporal patterns of the CP and CG in the AP direction for the reach task for an experienced subject

Performing the reach task on the 0° inclination



Performing the reach task on the 14° inclination



Performing the reach task on the 26° inclination

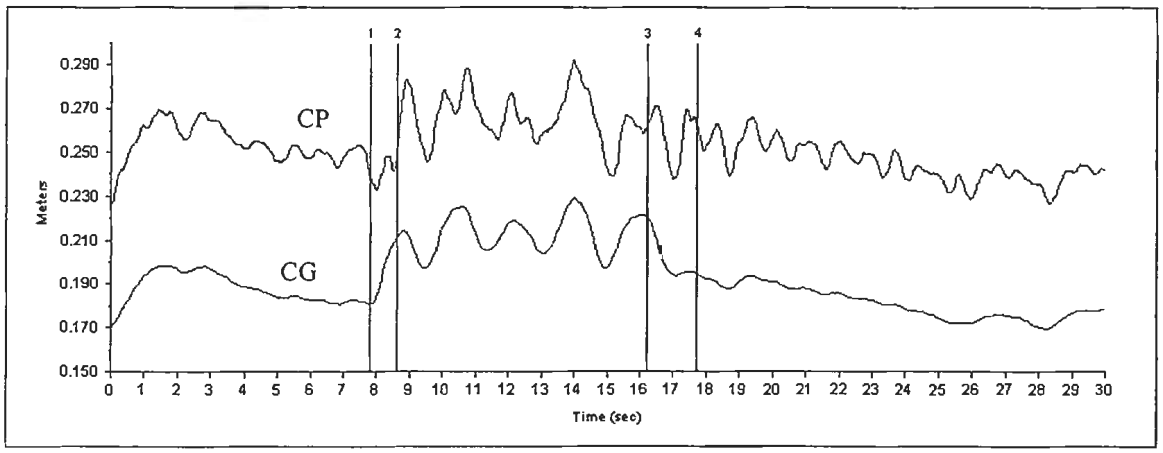


Figure 37. Temporal patterns of the CP and CG in the AP direction for the reach task for an inexperienced subject

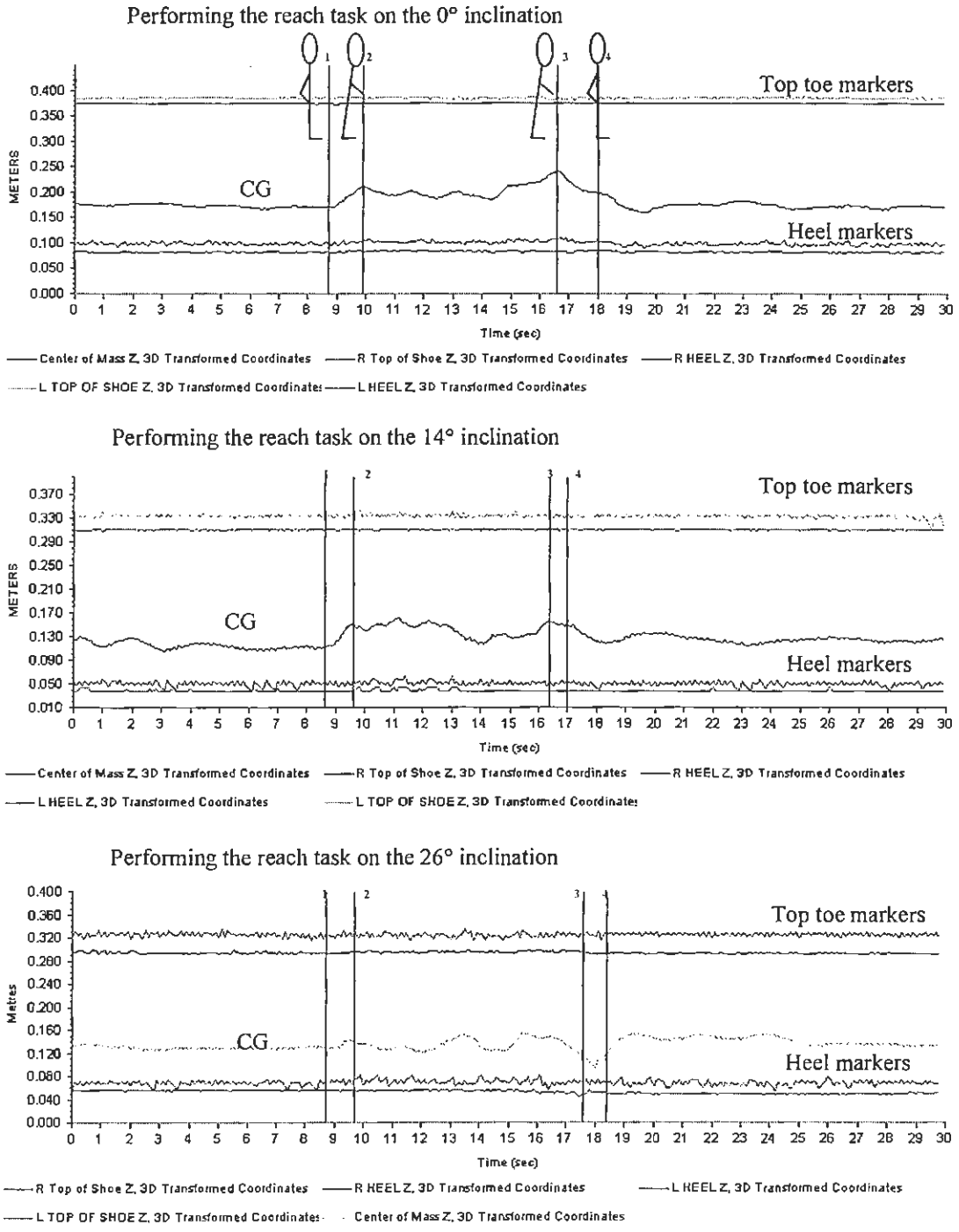


Figure 38. Temporal patterns of the CG with respect to the BOS in the AP direction for an experienced subject

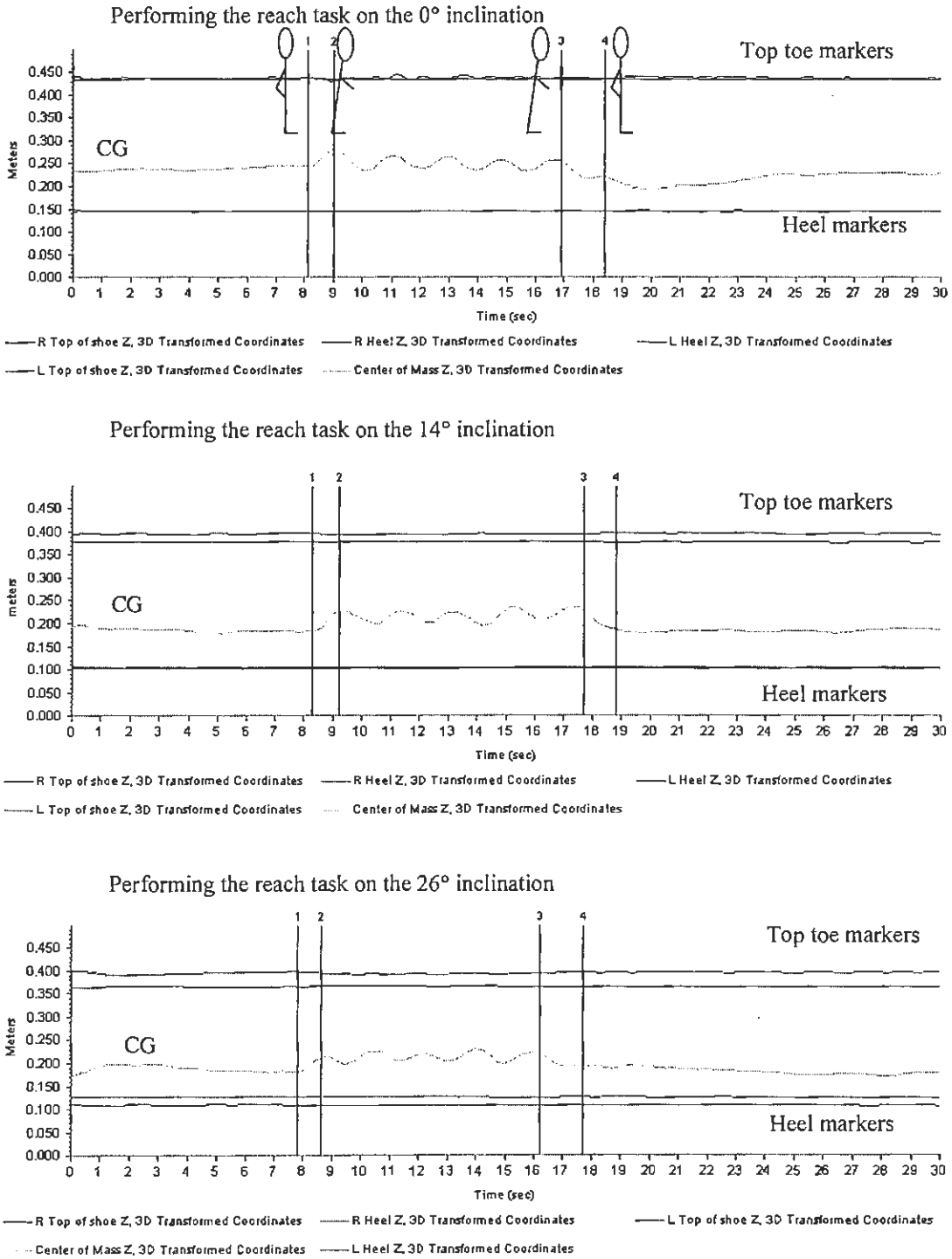


Figure 39. Temporal patterns of the CG with respect to the BOS in the AP direction for an inexperienced subject

Distance between the CG and the Heels of an experienced and inexperienced workers for the worst test condition on the inclinations: Tables 24 and 25 show the changes in the kinematic and kinetic parameters in the AP direction during a reach task for an experienced and an inexperienced workers. The initial distances (the distance at the beginning of the trial) between the CG and the heels for the experienced worker decreased as the inclination angle increased, whereas those for the inexperienced worker increased by 1 cm from the 0° to 14° inclination and decreased by 2 cm from the 0° to 26° inclination. The 26° inclination caused both the experienced and inexperienced workers to move their body CG toward their heels by 3 and 2 cm in the AP direction, respectively.

Table 24. Changes in the kinematic and kinetic parameters in the AP direction during the reach task in the worst test condition on the 0°, 14° and 26° inclinations (data from an experienced worker)

Kinematic and Kinetic Parameters	Inclination		
	0°	14°	26°
Range of the body's CG movement during reach (cm)	7	5	6
Range of the CP movement of the feet during reach (cm)	9	10	10
Initial distance between the body's CG and the heels (cm)	10	9	7
Initial hip angle (degrees)	174	176	162
Hip angle at the weight pick-up (degrees)	150	150	150
Hip angle change from the initial standing position to the weight pick-up (degrees)	24	26	12

Table 25. Changes in the kinematic and kinetic parameters in the AP direction during the reach task in the worst test condition on the 0°, 14° and 26° inclinations (data from an inexperienced worker)

Kinematic and Kinetic Parameters	Inclination		
	0°	14°	26°
Range of the body's CG movement during reach (cm)	6	5	5
Range of the CP movement of the feet during reach (cm)	8	6.5	6
Initial distance between the body's CG and the heels (cm)	8	9	6
Initial hip angle (degrees)	170	160	170
Hip angle at the weight pick-up (degrees)	160	162	160
Hip angle change from the initial standing position to the weight pick-up (degrees)	10	8	10

Temporal EMG patterns of an experienced and an inexperienced worker for the worst test condition on the inclinations

EMG activity of the quadriceps of an experienced and an inexperience workers for the worst test condition on the inclined surfaces: As shown in Figures 40, 42, 44, 46, 48 and 50, the left quadriceps of both experienced and the inexperienced workers were relatively inactive throughout the trial on all inclinations. However, for the experienced worker while the right quadriceps was relatively inactive for the 0 degree inclination, the 14 degrees inclination produced significant activity before (event 1) the inception of lifting phase of the reach task.

(figures 40 and 42) and then it stayed relatively calm for the remaining task period. On 26 degrees, the RQ response of experienced worker was very active both before (event 2) and after (event 4) the lifting phase of reach task with no activities during the lifting phase (figure 44). In contrast the inexperienced worker did not show any RQ activities during the entire test period for any of the inclinations (figures 46,48 and 50).

EMG activity of the hamstrings of an experienced and an inexperience workers for the worst test condition on the inclinations: As shown in Figures 40, 42, 44, 46, 48 and 50, the hamstrings of the both experienced and inexperienced workers were very active during the lifting phase of the reach task on the 3 inclinations. The hamstrings of the experienced worker were inactive before and after the lifting phase of reach task on the three inclinations, whereas those of the inexperienced worker were slightly active before and after the reach task on the 14° and 26° inclinations.

EMG activity of the tibialis anterior of an experienced and an inexperience workers for the worst test condition on the inclinations: As shown in Figures 47,49 and 51, the tibialis anterior (right and left) of the inexperienced worker were inactive except some spike activities on the 26° inclination. However, the left and right tibialis anterior of the experienced worker were inactive on the 0° inclination for the entire test period. During the reach task on 14 degrees inclination experienced worker's left tibilias showed almost no activity during the entire test period while the right tibilias was very active before the lifting phase (event 2). It should be noted that in the Figure 45, the left and right tibialis anterior of the experienced worker were active throughout the trials on the 26° inclination except for some silent periods due to the antagonistic effect of the gastrocnemius while performing the reach task. This antagonistic relationship between the tibialis anterior and the gastrocnemius for the inexperience worker was not observed (see Figure 51).

EMG activity of the gastrocnemius of an experienced and an inexperience workers for the worst test condition on the inclinations: As shown in Figures 41,43,45,47,49 and 51, the gastrocnemius of the both experienced and inexperienced workers were very active during the lifting phase of the reach task on the three inclinations. The gastrocnemius of the experienced worker was relatively inactive for the reminder of the trials on the three inclinations, while that of the inexperienced worker was slightly active before (event 1) and after (event 4) the lifting phase of the reach task on all inclinations. The activity of the gastrocnemius during the reach task seemed to increase as the inclination angle increased for the experienced workers more than those observed for the inexperienced.

To summarize the EMG activity patterns of the experienced and inexperienced workers for the worst test conditions, the quadriceps of both workers were inactive except that the RQ of the experienced worker was slightly active before the lifting phase of the reach task. In general, the hamstrings and gastrocnemius of the both workers were active during reach regardless of on which incline. The EMG activity of the tibialis anterior of the experienced worker seemed to increase as the inclination angle increased. However, this trend was not observed in the inexperienced worker. An antagonistic relationship between the tibialis anterior and the gastrocnemius was observed in the experienced worker while performing the reach task on the 26° inclination; however, this relationship was not found in the inexperienced worker due to a

lack of the EMG activity of the tibialis anterior in the inexperienced worker.

The EMG activity of the 8 muscles of an experienced and inexperienced workers in the best test condition on the three inclinations are similar to those before performing the reach task. The effects of the visual cues and fatigue were not observed in the EMG activity of these muscles. The tibialis anterior was active on the 26° inclination, as it was on in the worst test condition on the 26° inclination. The quadriceps were slightly active on the 26° inclination as they were in the worst test condition on the 26° inclination.

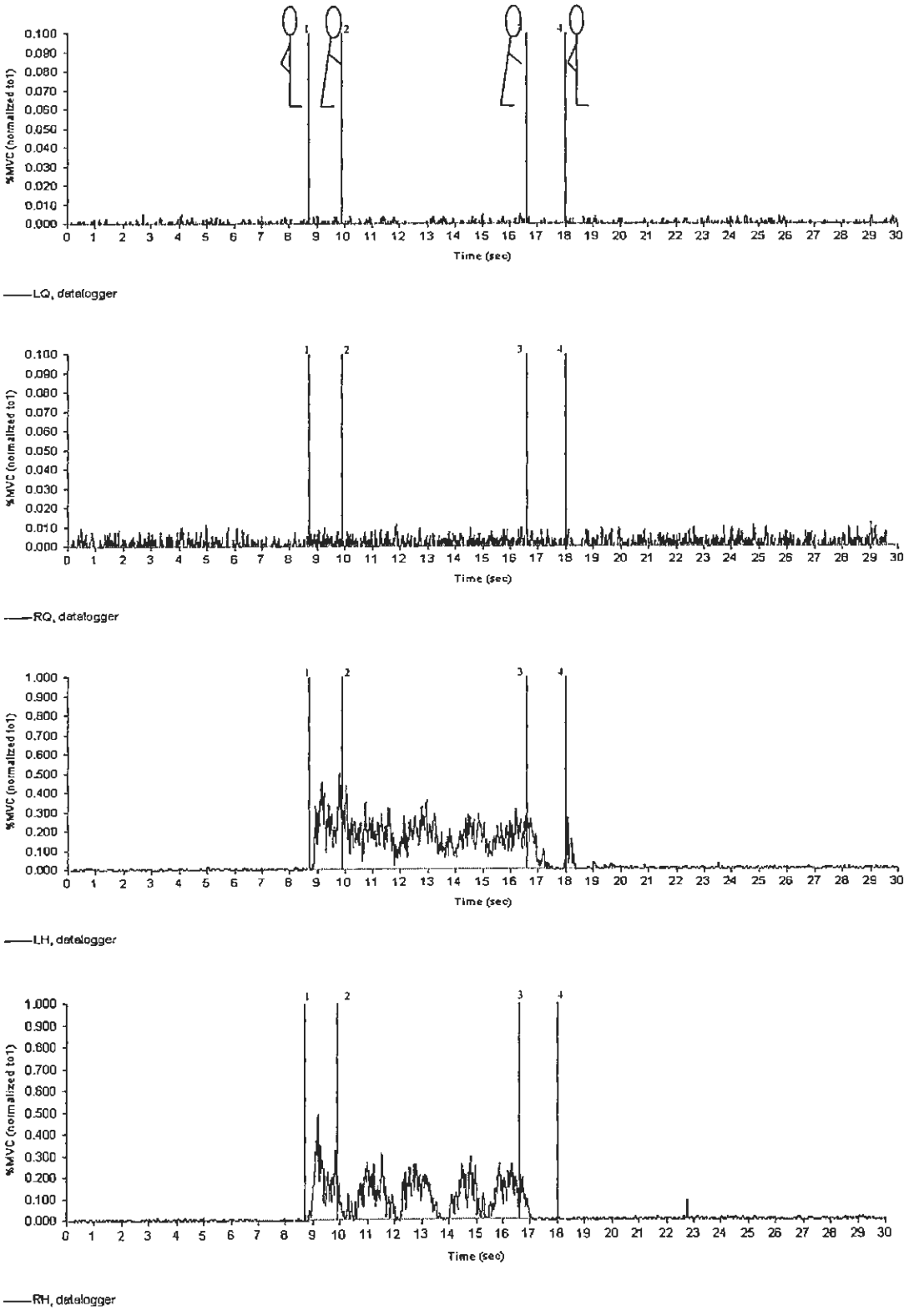


Figure 40. Temporal EMG patterns of the quadriceps and hamstrings while performing the reach task on the 0° inclination for an experienced subject

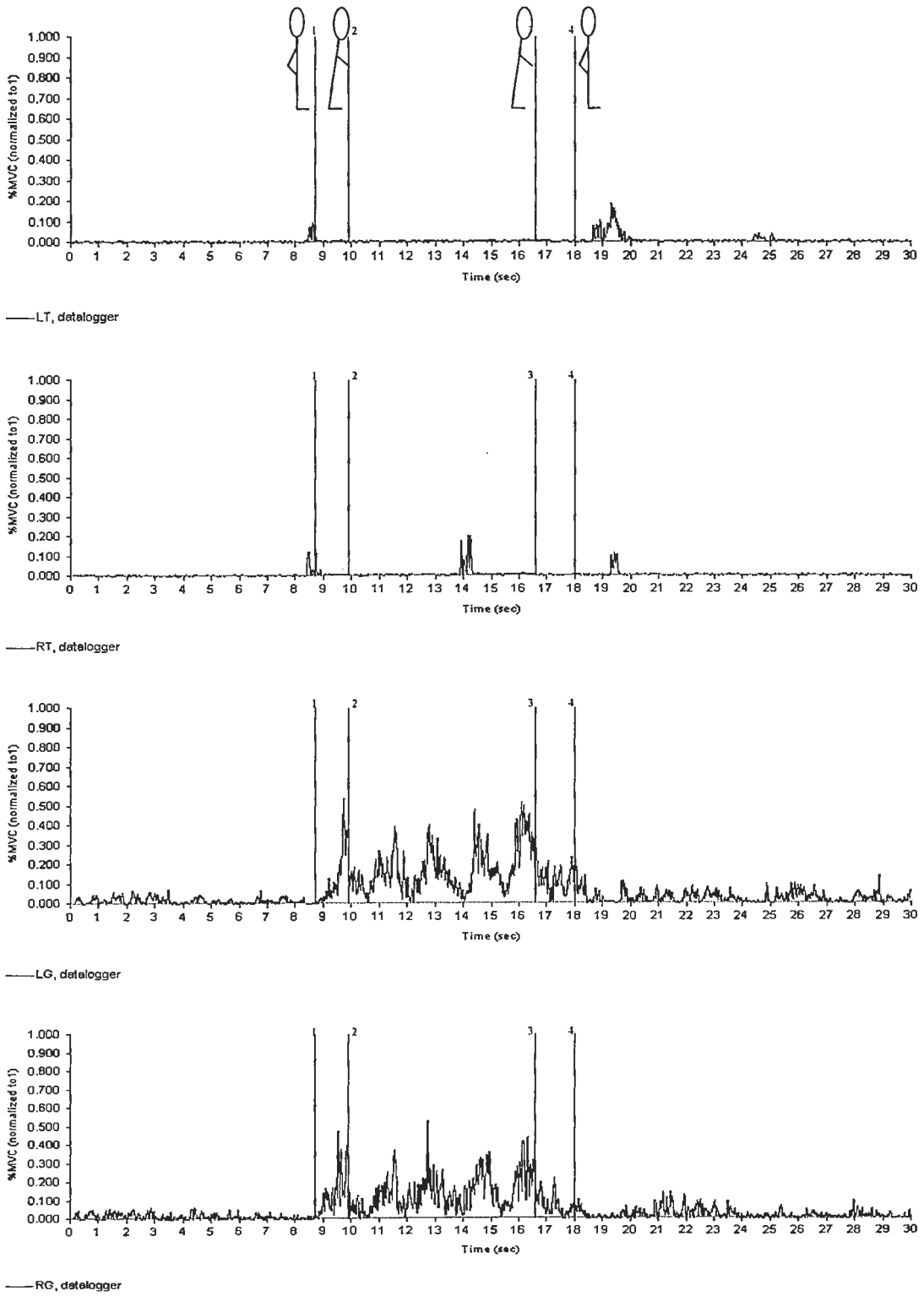


Figure 41. Temporal EMG patterns of the tibialis anterior and gastrocnemius while performing the reach task on the 0° inclination for an experienced subject

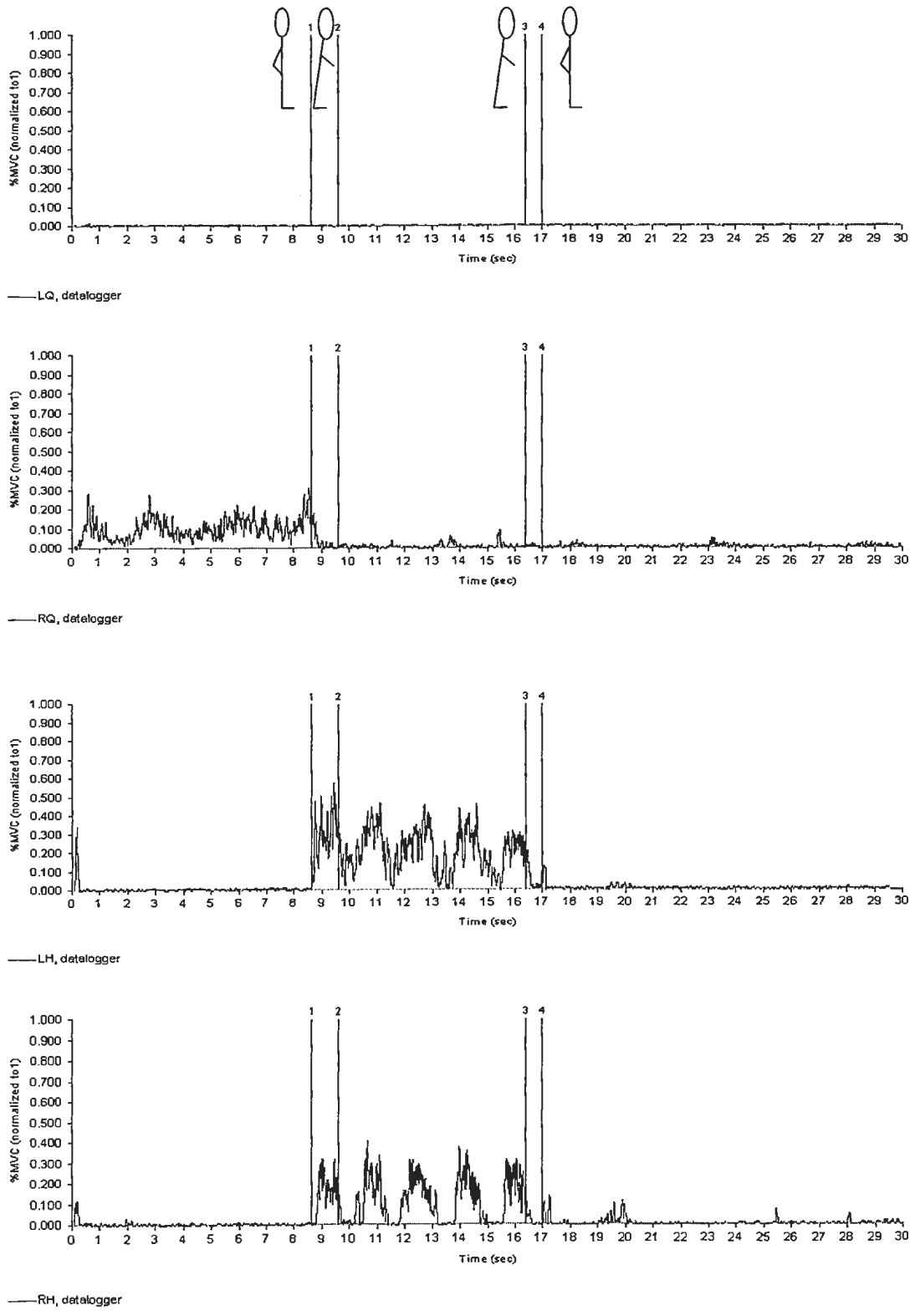


Figure 42. Temporal EMG patterns of the quadriceps and hamstrings while performing the reach task on the 14° inclination for an experienced subject

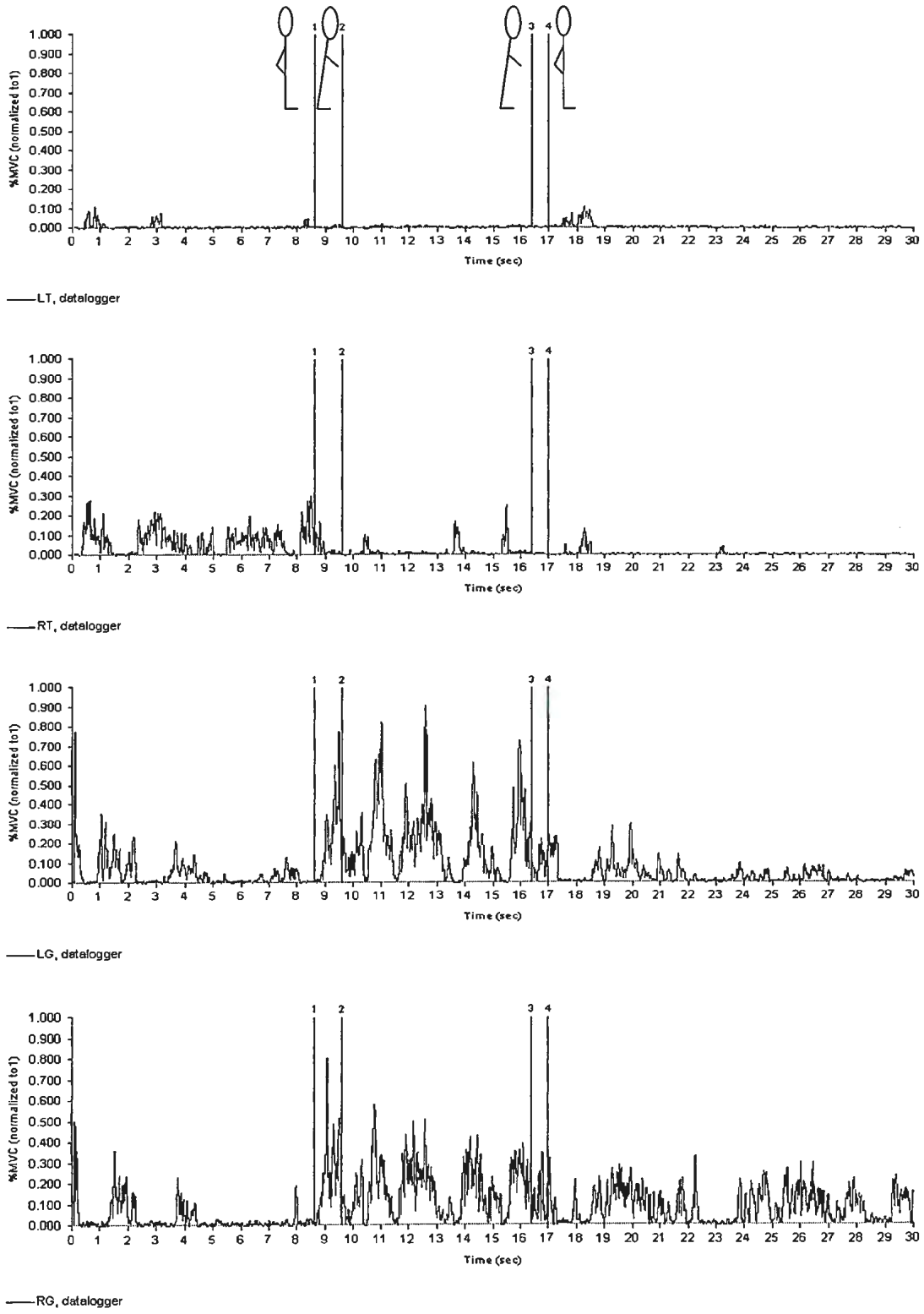


Figure 43. Temporal EMG patterns of the tibialis anterior and gastrocnemius while performing the reach task on the 14° inclination for an experienced subject

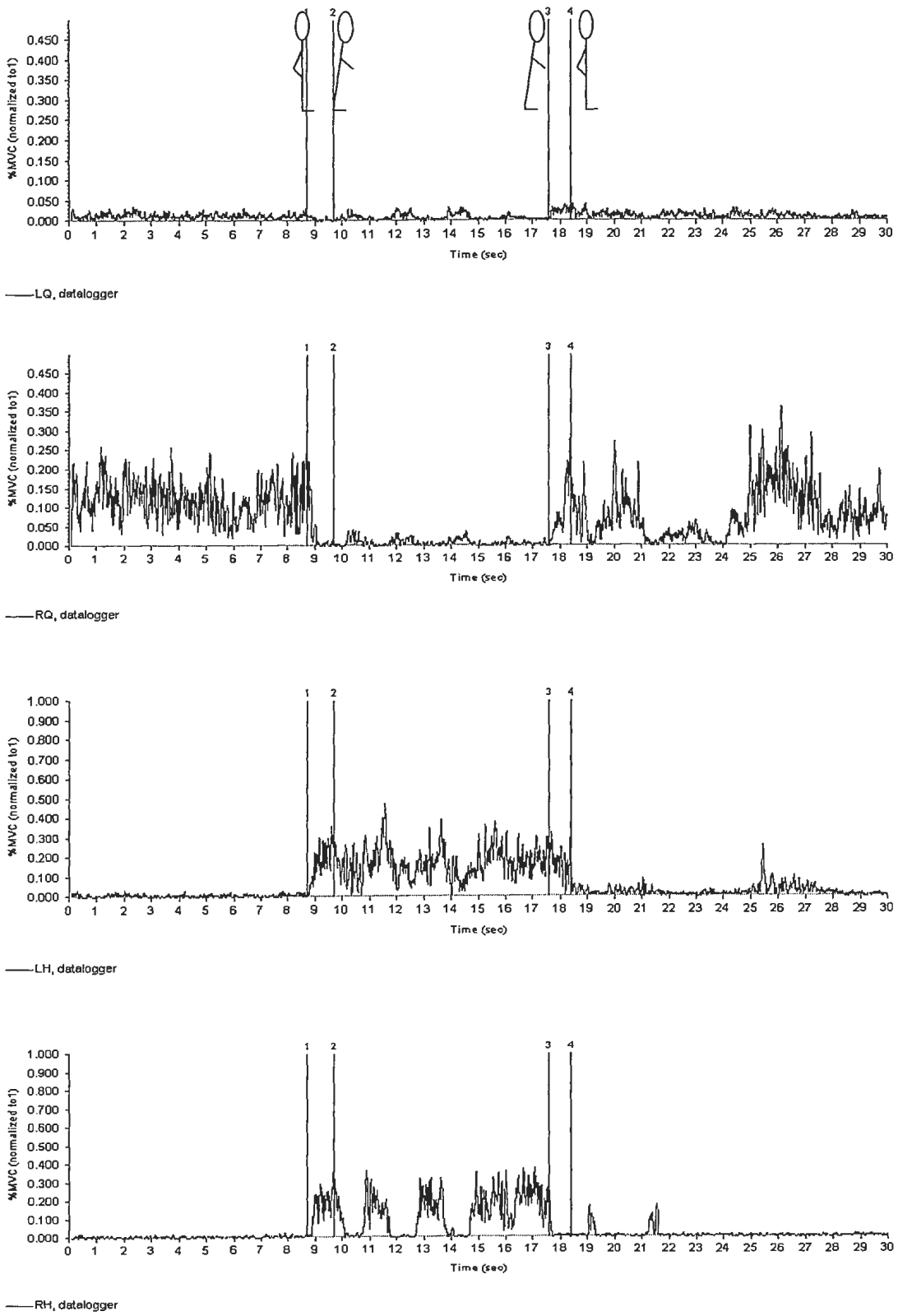


Figure 44. Temporal EMG patterns of the quadriceps and hamstrings while performing the reach task on the 26° inclination for an experienced subject

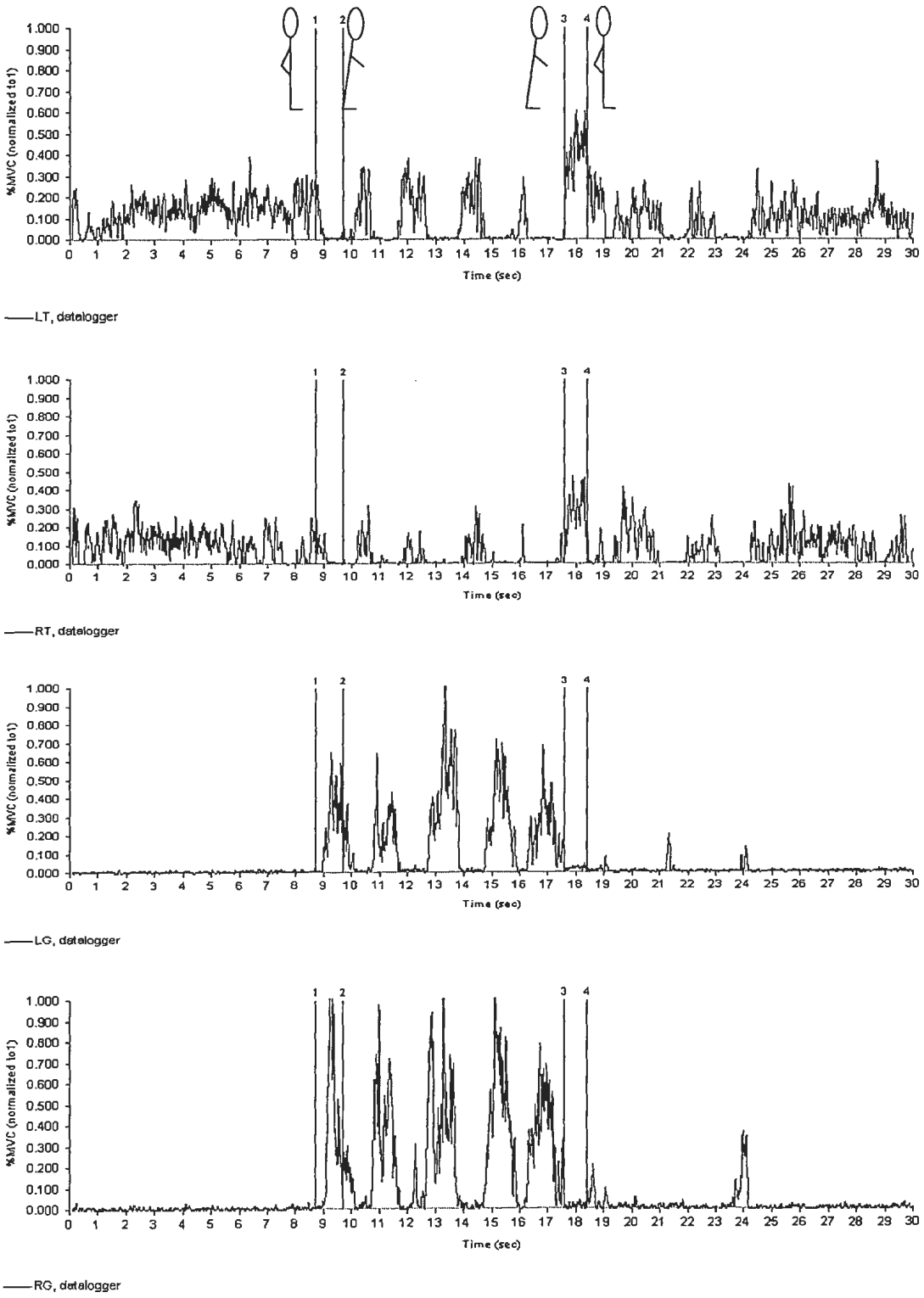


Figure 45. Temporal EMG patterns of the tibialis anterior and gastrocnemius while performing the reach task on the 26° inclination for an experienced subject

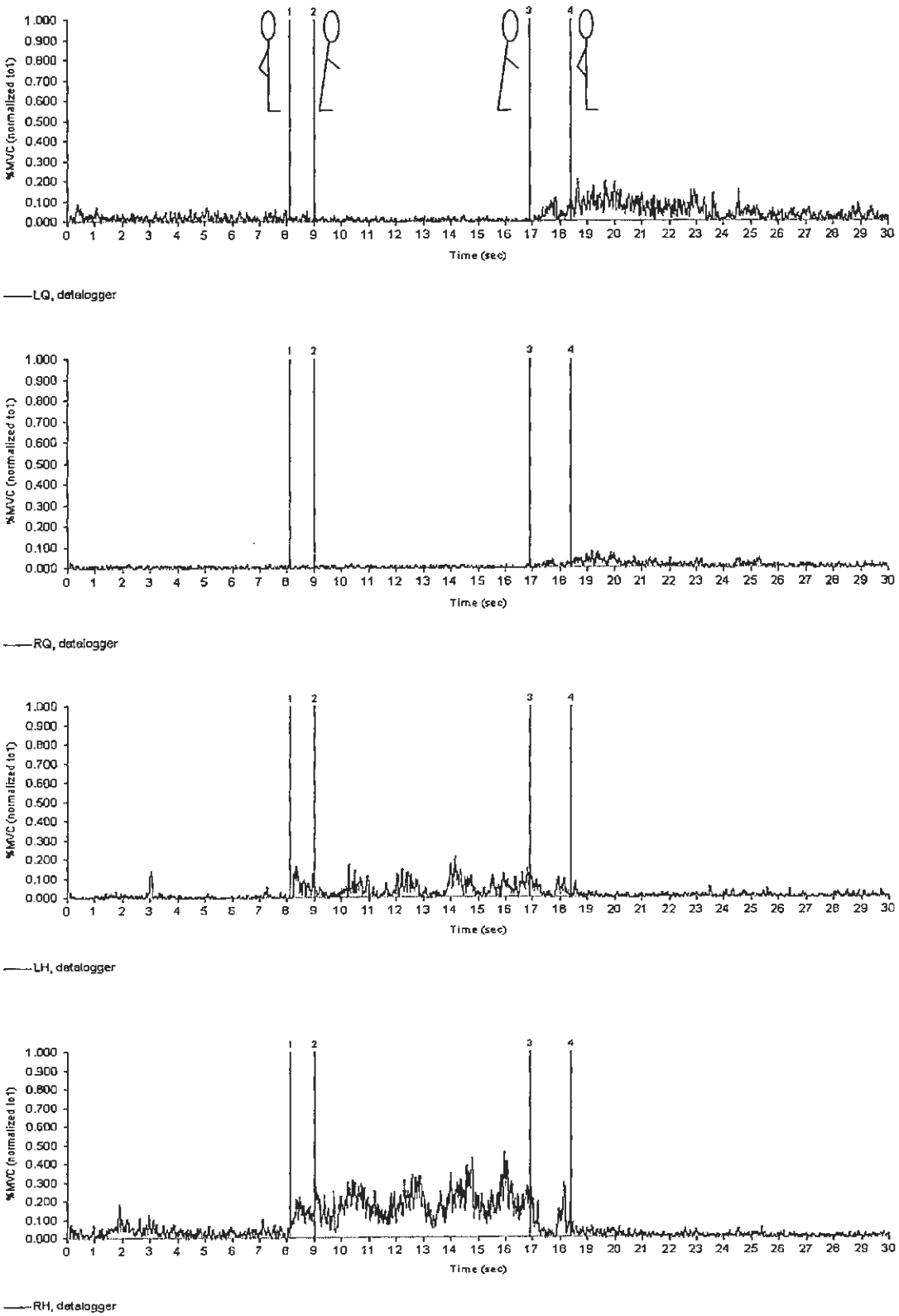


Figure 46. Temporal EMG patterns of the quadriceps and hamstrings while performing the reach task on the 0° inclination for an inexperienced subject

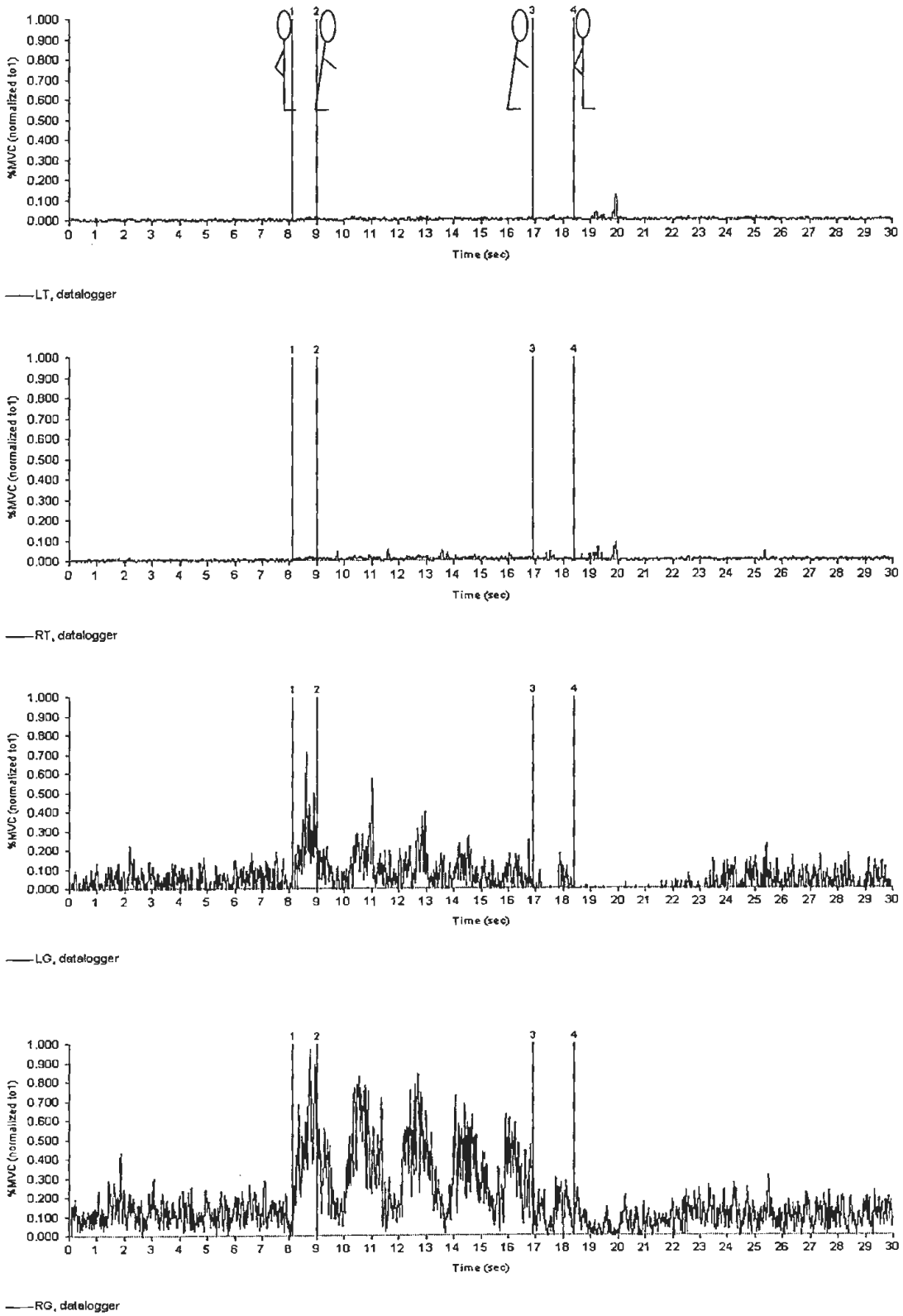


Figure 47. Temporal EMG patterns of the tibialis anterior and gastrocnemius while performing the reach task on the 0° inclination for an inexperienced subject

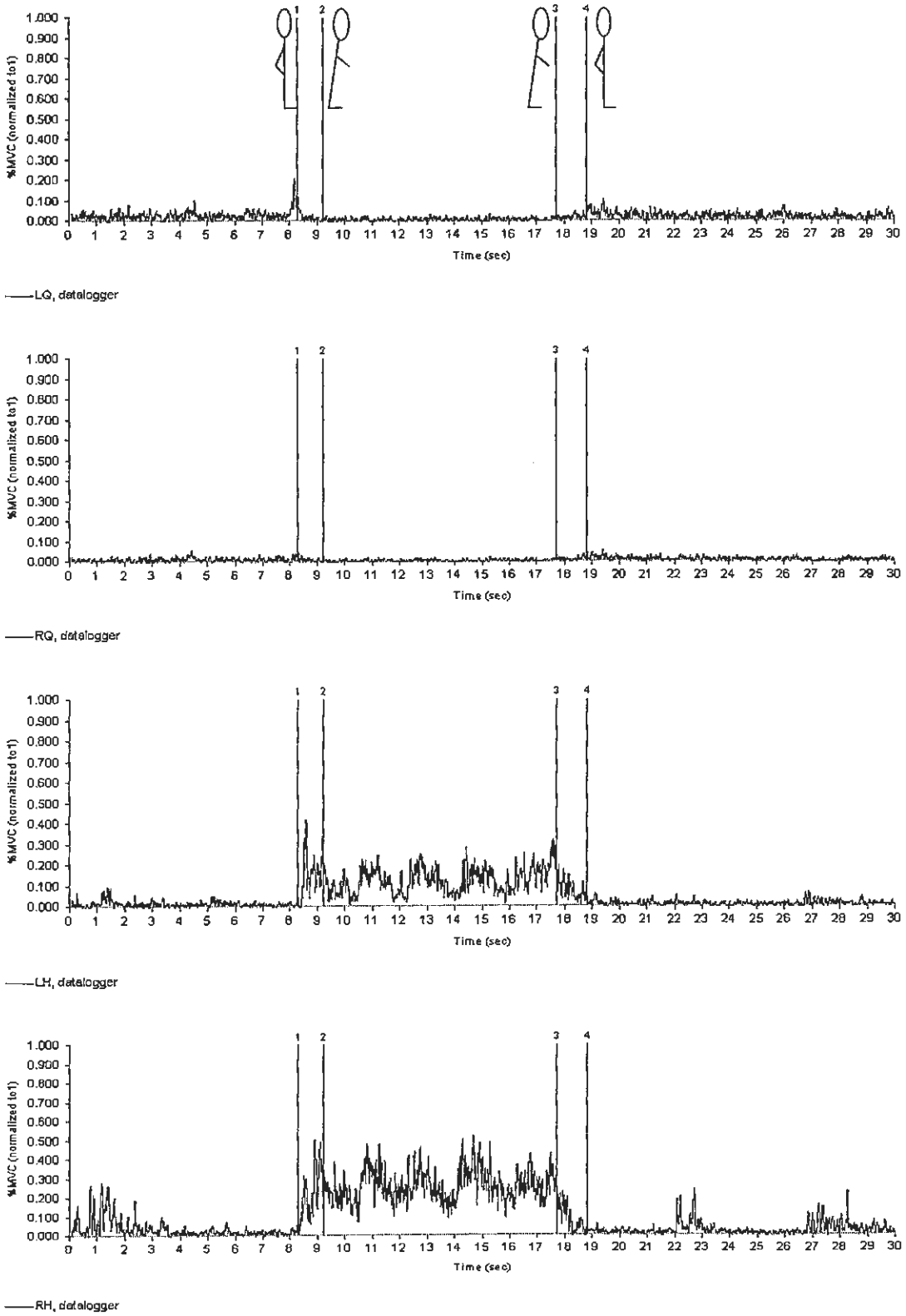


Figure 48. Temporal EMG patterns of the quadriceps and hamstrings while performing the reach task on the 14° inclination for an inexperienced subject

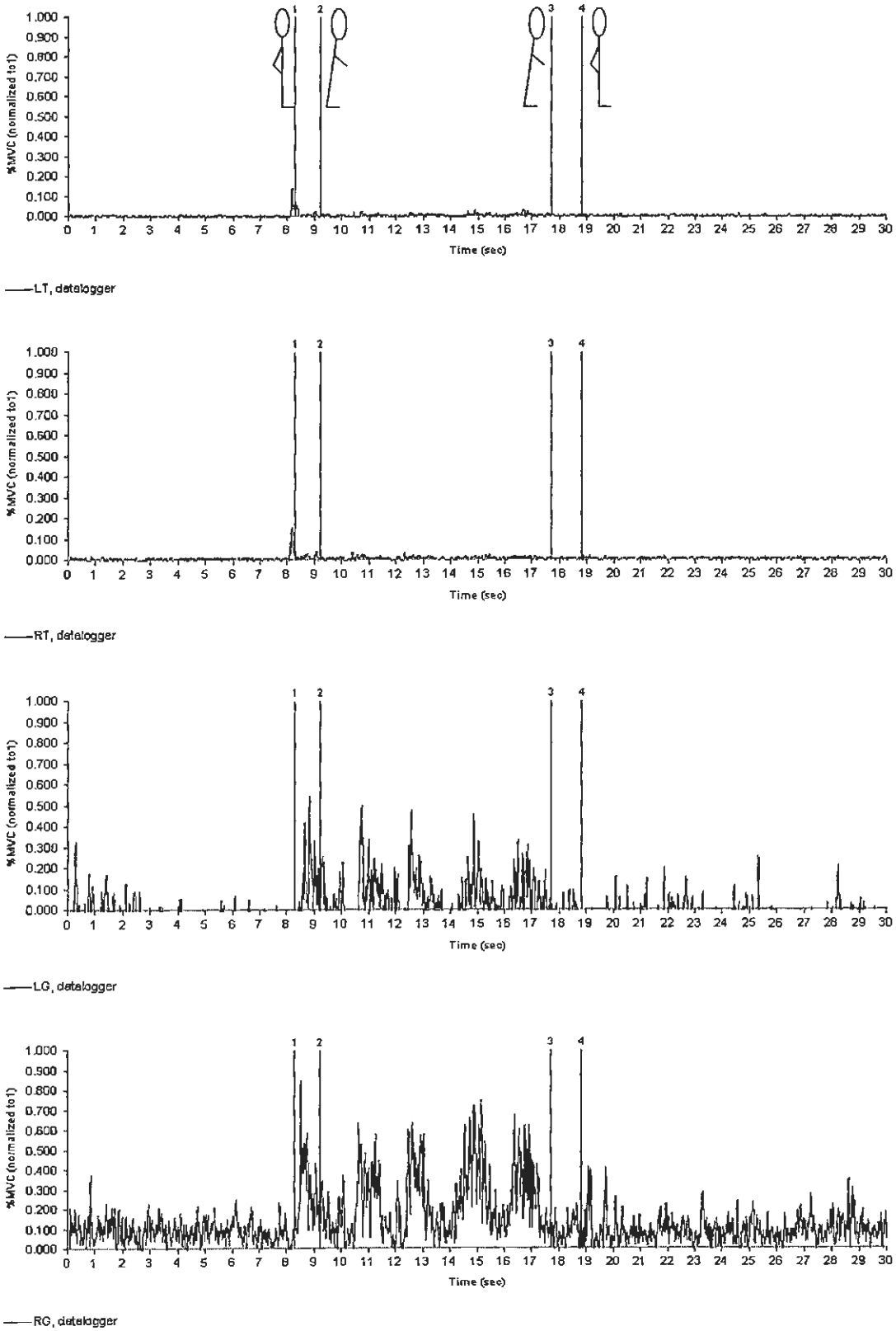


Figure 49. Temporal EMG patterns of the tibialis anterior and gastrocnemius while performing the reach task on the 14° inclination for an inexperienced subject

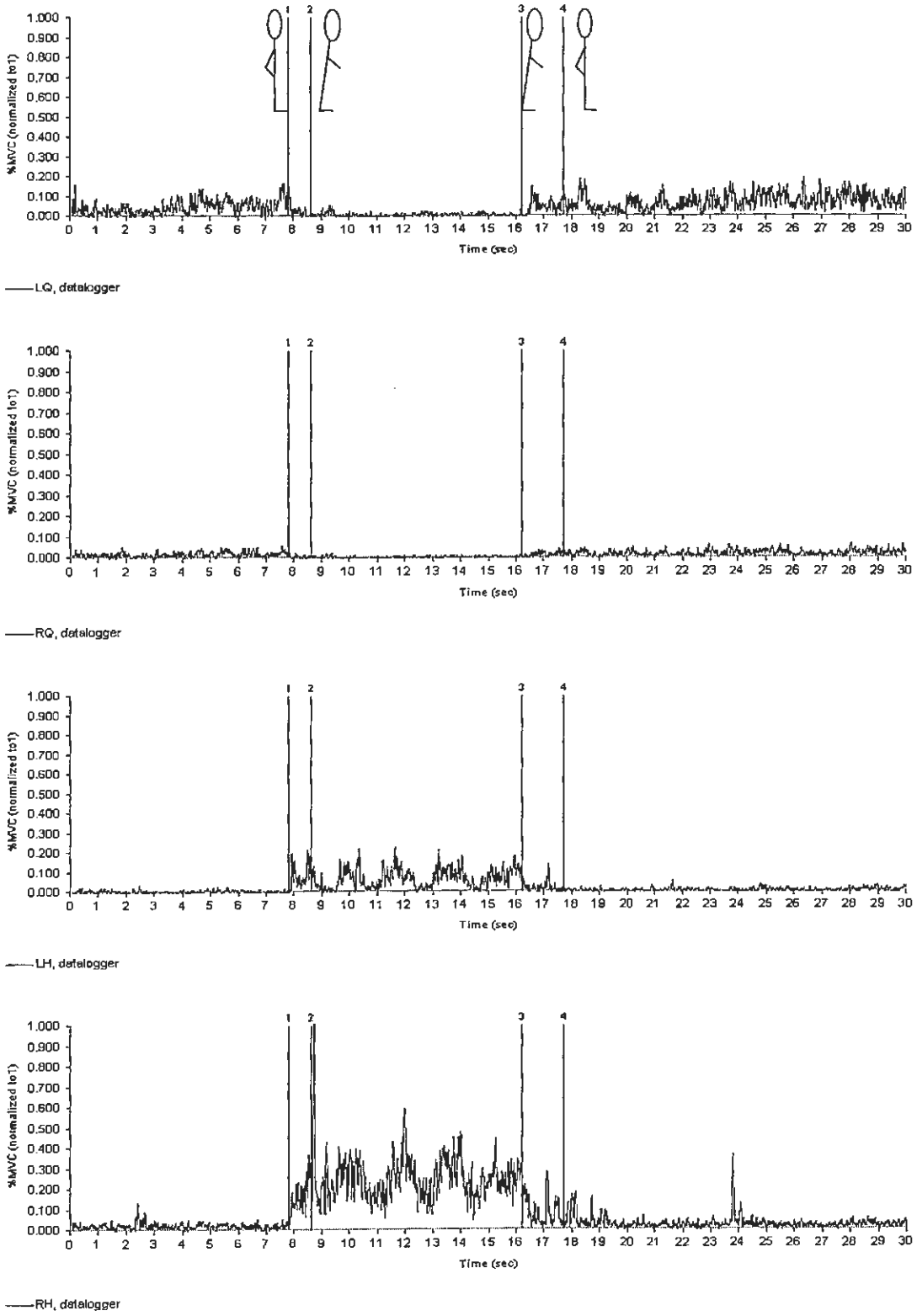


Figure 50. Temporal EMG patterns of the quadriceps and hamstrings while performing the reach task on the 26° inclination for an inexperienced subject

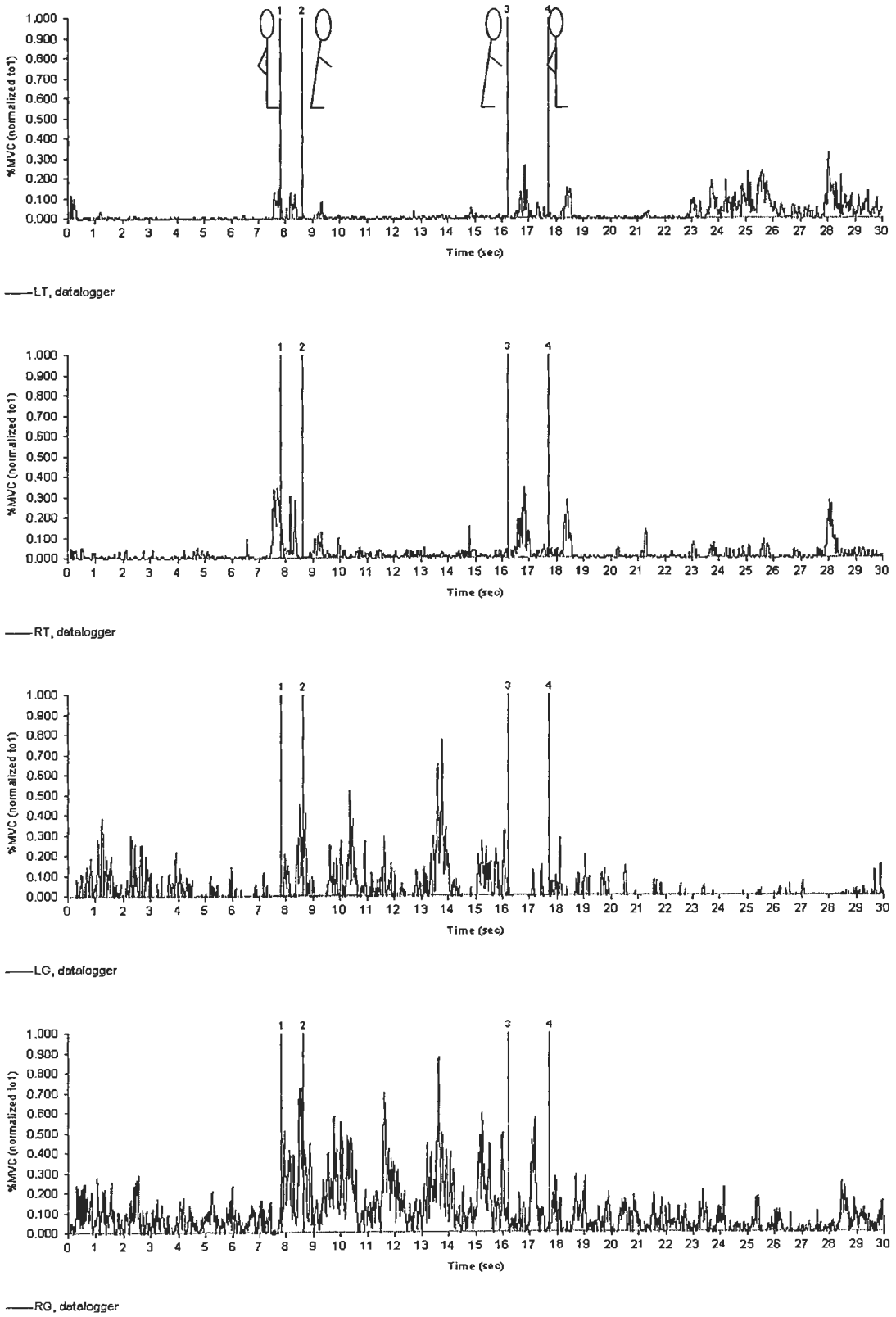


Figure 51. Temporal EMG patterns of the tibialis anterior and gastrocnemius while performing the reach task on the 26° inclination for an inexperienced subject

D.3.2. Effect of the Fatiguing Tasks on the EMG Signal

Table 26 shows the means and standard deviations (SD) of the change in the MF over time from a power frequency spectral analysis of the EMG activities of the 8 muscle groups. The intercept of the MF curve over time represents the initial MF of the power frequency spectrum for the muscle. Student's t-test was used to test for differences in the rate of change of the MF from time (Ho: no significant MF change from the initial MF) during each fatiguing task. A statistically significant decrease in the rate of change of the MF (negative sign) indicated the onset of fatigue during the muscular contraction for the fatiguing task. The t-tests showed that the rates of change of the MF for the LH, RH and RT for the full fatiguing task were significantly less from 0 ($p<0.008$, $p<0.002$ and $p<0.007$, respectively). This means that the LH, RH and RT among the 8 muscle groups were fatigued as described by the rate of change of the MF during the full fatiguing task. The change rates of the MF for the LH, RH and RT for the full fatiguing task were –0.26, -0.33 and –0.16, respectively.

The average initial MF's for the 8 muscles are shown in Figure 52 (also refer to Table 18 for the corresponding values). Results from a general linear model for testing the differences in the initial MF between the three levels of the fatiguing tasks are also shown in Figure 52. The significant differences in the initial MF between three levels of the fatiguing tasks indicate that muscle length might affect the MF in the beginning of the semi-squatting fatiguing task. It was found that there was no statistical difference in the initial MF between the fatiguing tasks for the LH. For the remaining muscle groups, significant differences were found between no and half fatiguing tasks and between no and full fatiguing tasks. The initial MF for the RH was found to be significantly different between the three fatiguing tasks (all P's<0.05).

Table 26. Means and SD's of the slopes and intercepts of linear regression lines for median frequencies vs. time (data from fatigue pilot trials)

Fatigue	Variable	Lqslope	Lqintcpt	Lhslope	Lhintcpt	Ltslope	Ltintcpt	Lgslope	Lgintcpt	Rqslope	Rqintcpt	Rhslope	Rhintcpt	Rtslope	Rtintcpt	Rgslope	Rgintcpt
N	mean	0.04346	150.32	0.269014	98.777	0.1043	141.69	-0.0106	113.78	0.12423	119.9	0.04945	143.04	-0.0059	114.85	0.03204	136.02
H	mean	-0.169	64.549	-0.0569	93.341	-0.1698	118.09	-0.0733	103.65	0.14878	112.52	0.05151	114.73	-0.2353	95.345	-0.21018	64.544
F	mean	0.08432	63.604	**-0.26089***	95.096	-0.0909	121.38	-0.0633	104.86	0.14281	109.31	**-0.3372***	126.46	**-0.162***	93.243	0.025033	66.747
N	SD	0.21867	9.3987	0.529486	23.035	0.22754	10.408	0.20387	20.535	0.35551	13.232	0.17381	8.1621	0.2632	23.777	0.194411	31.652
H	SD	0.43802	19.025	0.834154	30.673	1.05865	23.038	0.42929	23.719	0.60107	18.484	0.80241	21.488	1.00954	30.722	0.503031	15.037
F	SD	0.35937	18.547	0.32595	21.677	0.18521	10.96	0.28994	25.569	0.31263	14.886	0.34812	16.303	0.19917	23.367	0.451031	14.559

Note: Lqslope and Lqintcpt: MF change rate and initial MF for left quadricepts, Lhslope and Lhintcpt: MF change rate and initial MF for left hamstrings; Ltslope and Ltintcpt: MF change rate and initial MF for left tibialis anterior; Lgslope and Lgintcpt: MF change rate and the initial MF for left gastrocnemius; Rqslope and Rqiintcpt: MF change rate and initial MF for right quadricepts, Rhslope and Rhintcpt: MF change rate and initial MF for right hamstrings; Rtslope and Rtintcpt: MF change rate and initial MF for right tibialis anterior; Rgslope and Rgintcpt: MF change rate and initial MF for right gastrocnemius.

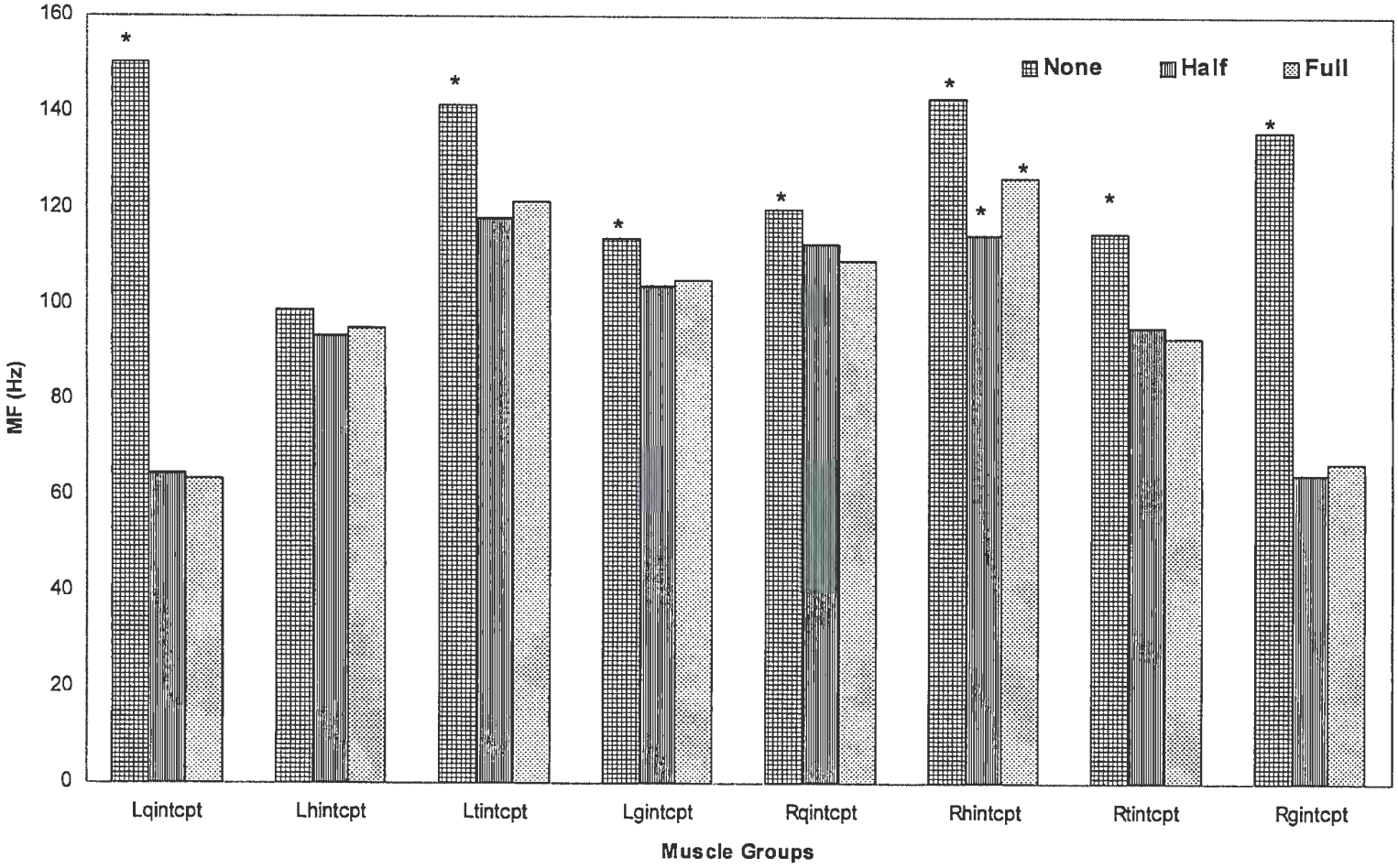


Figure 52. Initial MF of the 8 muscle groups for the fatigue pilot test.

*: statistically significant ($p<0.05$) in the MF between the fatiguing tasks.

D.3.3. EMG and Postural Sway Results and Discussion

All tables and figures for the EMG and Postural Sway analysis results can be seen in Appendix S. Separate structural equation models (SEMs) were performed for each of four postural sway outcome measurements [area, length, and excursion in the Medio-Lateral (X) and Anterior-Posterior (Y) direction] and 8 EMG measurements (left and right Gastrocnemus, Hamstrings, Quadriceps and Tibialis anterior; abbreviated LG, RG, LH, RH, LQ, RQ, and LT and RT). A schematic of the structural model design can be seen in figure 53. In the SEMs, the EMG data were treated as mediator variables, i.e., affected by the other exogenous variables in the models but predictors of the postural sway outcomes. The EMG data were captured at 5 different percentiles along the cumulative EMG activity curves (5th, 25th, 50th, 75th and 95th); a separate SEM was estimated for the EMG data measured at each of these percentiles. Three work experience variables: a dichotomous variable denoting work experience on inclined and/or elevated surfaces; a continuous variable representing the number of years of such work experience; and a continuous variable for the number of hours of such work activities per week were tested in separate SEMs. Thus, a total of 15 separate SEMs were estimated for these data (5 EMG percentiles measured X 3 work experience variables). Three loading variables were analyzed as exogenous factors: the fatiguing task that the worker performed during each trial, a trichotomous variable; the continuous Borg scale rated by the worker after each trial; and the continuous Bishop scale rated by each worker immediately after each trial. In each of these analyses, the experimental conditions of task performed (reach vs. stationary), inclination angle (0, 14 or 26 degrees) and the presence of a visual cue (yes/no) were treated as exogenous variables. The interactions between the experience factor used in each model with load, task performed, inclination and cue were also tested for significance on the EMG and postural sway outcomes. Other covariates (e.g., age, gender, height and muscle strength) were analyzed for statistical significance. The interaction between the experience factor used in each model and muscle strength also was included as an exogenous factor, primarily due to the observation (Table 20) that experienced workers tended to have greater muscle strength. Covariates and interactions that were not significant at the $p < 0.05$ level were removed from the statistical models in a backward elimination process. The work experience and experimental condition variables, including the trichotomous fatiguing task factor, were forced into each of the SEMs and their statistical significance evaluated in the final models that included only statistically significant covariates.

The p-values from the SEMs for the effects of work experience, load and the experimental conditions on each of the EMG and postural sway outcomes, and for the effects of EMG on sway are shown in Tables S-1, S-4, S-7, S-10, S-13. Since multiple models were run for each of the factors other than the experience variables for each EMG activity percentile (3 models were developed for each of the experimental conditions), the range of the p-values from these models is tabled. The range of p-values was generally small, and in only a few cases did the multiple models analyzed for each of these factors differ in terms of their statistical significance on any of the EMG or sway outcomes. One-tail p-values are shown for the dichotomous factors of work

experience, task and visual cue and the continuous predictors of the sway outcomes (i.e., years of work experience, hours of work activity, and the Borg and Bishop scales). Two-tail p-values are shown otherwise (i.e., for the trichotomous factors of the fatiguing task performed and the inclination factor) and for all predictors of the EMG outcomes. The least square means (geometric means for the EMG data and for all sway data) for each of the categorical factors are shown in Tables S-2, S-5, S-8, S-11, S-14. The median least square mean from the multiple models analyzed is shown for the experimental conditions' main effects and for the interactions among the experimental conditions.

The main effects of task type and surface inclination were found to significantly affect postural sway variables. (Tables S-1, S-4, S-7, S-10, S-13). All four sway variables showed significant effect due to task types and inclination for all 5 models (95^{th}, 75^{th}, 50^{th}, 25^{th} and 5^{th} percentile of EMG activity). In other words, in comparison to the stationary task all sway variables increased for the reach task implying poorer postural balance. Similarly, with increasing inclination angle from 0 degrees to 26 degrees all sway variables except for AP excursion (with respect to 0 degree it decreased for 14 degree but increased for 26 degrees) increased implying poorer postural balance. This finding is consistent with our previous study of task performance on inclined and elevated surfaces (Final Performance Report: Fall Potential of Work on Elevated and Inclined Surfaces. R01-OH03107-03). The main effects of visual cue on the postural sway variables were found for only sway length for two models (25^{th} and 5^{th} percentile of EMG activity). For other three models (95^{th}, 75^{th} and 50^{th} percentile of EMG activity) the sway length was marginally (p value range: (0.05 –0.1) influenced by visual cue.

The main effect of experience was not found to significantly influence postural sway in most of the SEMs. The dichotomous experience factor significantly affected sway area ($p<0.0001$) in only one of the five models (95th percentile of EMG activity) and excursion in the M-L direction ($p<0.04$) in another (50th percentile of EMG activity). Months of work experience was a significant predictor of sway area in the model involving the 75th percentile of EMG activity ($p<0.0001$) and of excursion in the AP direction in the model involving the 5th percentile of EMG activity ($p<0.0001$). Weekly hours of work activity on an inclined or elevated surface was not significantly related to sway in any of the five models that utilized different EMG activity data. The experience factors, however, were found to be significantly interacted with task in a number of these SEMs. The experience X task interaction significantly predicted sway length in each of the five models; in addition, this interaction also predicted sway area and excursion in the AP direction for all but the SEM involving the 95th percentile of EMG activity data. These interactions indicated that experienced workers tended to experience more postural sway (shown by higher sway length) in the stationary condition as compared to inexperienced workers. Experienced workers' sway length was approximately 20% greater (than inexperienced workers) under stationary condition, as compared to only about a 6% increase for the experienced workers during the reach task. A similar, albeit weaker interaction of work activity hours with task was observed to affect postural sway, but only for the excursion in the AP direction and only for the models involving the lower EMG activity percentiles (25th and 5th percentile EMG activity

models). A higher postural sway in experienced workers than that observed in the inexperienced individual was not expected. This unexpected finding can be explained by examining the subjective perception of postural stability and EMG data and is presented next. In the current study we noted significant interaction between continuous variable of Exp_job and inclination, Activity X task, Activity X incline and the categorical variable of Exp X incline (Table 27). For example, the least squares means data (Table 28) indicated that the subjective perception of postural stability PSOF scores were higher for the experienced group (when categorical definition for experience was used) than that of inexperienced person as inclination level increased implying that experienced group were experiencing a higher postural sway as shown by LS means values of sway variables (Tables S1-S15) compared to the inexperienced group. However with an increased sway among the experienced group we should have observed a higher EMG activity than those in the inexperienced group but we see the opposite response (Tables S1-S15). On the other hand when we consider interaction between inclination and the experience as defined as a continuous variable of EXP_job we see a different response patterns. In this case with increasing experience on job (months) and inclination of the surface the PSOF scores decrease (figure 54) implying that with experience workers perceive task performance on increasing inclination is less of a threat to their postural stability. Assuming this line of logic one can theorize that if experience brings on increasing confidence regarding their ability to maintain upright posture on inclined surface then postural muscles will not have to contract as hard as those without experience. The EMG results do support this line of thinking i.e. experience workers have lower amount of EMG activity compared to that of inexperienced group (Tables S1-S15). However a decrease in postural EMG activity should have produced a lower sway among the experienced group than those in the inexperienced group but the results of sway show the opposite response (Tables S1-S15). Therefore there appears to be a disconnection between EMG and sway outcome response and is further documented in the following paragraph. Such a disconnect between EMG of leg muscles and the sway variables (measured by the force platform system) is probably not unexpected since postural sway is produced not only by the postural leg muscles (those measured in the current study) but trunk muscles (not measured) and inertial movement of the upper body contribute significantly while performing task on inclined surface. Since trunk muscles contractions and the upper body movement patterns were not available it is not unusual that EMG of the leg muscles alone do not predict sway.

The experience variables tended to be more highly related to the EMG outcomes, both as main effects and when interacted with the experimental conditions and muscle strength. The dichotomous experience factor was significantly related to as many as 7 of 8 of the EMG variables at the 95th percentile of activity, and as few as 3 for the 75th and 25th percentiles of activity or 2 at the 50th and 5th percentiles of activity. Months of experience was significantly related to 6 of the 8 EMG outcomes at the 95th and 50th percentiles of activity; 5 at the 25th percentile; and 3 at the 75th and 5th percentiles. Hours of work activity was significantly related to 6 of the 8 EMG outcomes at the 95th percentile of EMG activity; four at the 50th; and 3 at the 75th, 25th and 5th percentiles of EMG activity. In the vast majority of these models, greater experience or work activity predicted that the worker would experience lessened EMG activity.

This is expected since increased EMG implies more muscle contraction, which in cumulative sense will bring about muscle fatigue. Therefore the results imply that experienced workers are using lesser amount of muscle activity to perform the task as compared to inexperienced worker. Experience was found to be significantly interacted with the inclination factor for 3 of the EMG outcomes in each of the models, the exception being the one fit for the 95th percentile data, where no significant experience X inclination interactions were found. Similarly, the hours of work activity X inclination interaction was significant for at least one of the muscle groups' EMG activities at each percentile (for one, three, four, five, and two at the 95th, 75th, 50th, 25th and 5th percentiles of activity, respectively) and the years of experience on the job variable also was often significantly interacted with the inclination factor in predicting EMG activity, particularly at the inter-quartile percentiles. This experience variable was significantly interacted with the inclination factor for none, two, four, two and none of the 8 EMG muscle groups at the 95th, 75th, 50th, 25th and 5th percentiles of activity, respectively. These interactions almost invariably indicated that the experienced workers' EMG activity increased to a lesser degree, or even declined, as the inclination angle increased from 0 to 26 degrees, relative to the EMG activity of inexperienced workers implying that experienced worker would be at a lesser degree of developing muscle fatigue if the task are carried out for prolonged period. Experience was also found to be significantly interacted with task, but only for two of the muscle groups' 75th percentile of activity; for the EMG of the RG muscles' 25th percentile of activity, the years of work experience variable also was found to be significantly interacted with task. These interactions indicated that experienced workers tended to have less of an increase of EMG activity relative to inexperienced workers when performing the reach task again implying that experienced workers will not experience fatigue as much as the inexperienced ones. Finally, a number of muscle strength variables were found to be significantly interacted with the experience factors in these models, indicating that experienced workers tended to need to use less muscle strength for a given level of EMG activity.

In the SEMs, EMG served as a mediating variable between the conditions of the experiment and postural sway. Thus, the experimental conditions and the experience factors could exert indirect effects on the postural sway outcomes through the EMG mediators. However, only a limited number of EMG effects on the postural sway outcomes were found in the SEMs. The LG activities were found to affect excursion in the M-L (X) direction (95th percentile model only), sway area (75th and 50th percentile models), sway length (50th, 25th and 5th percentiles models) and excursion in the AP (Y) direction (50th percentile model). LH was found to significantly predict sway area at the 95th, 25th and 5th percentiles of activity and sway length at the 95th percentile of activity. RG significantly predicted sway area at the 75th, 50th and 25th percentiles of activity; sway length and excursion in the AP direction at the 75th percentile; and excursion in the M-L direction at the 5th percentile of activity. RH predicted sway length, but only at the 75th percentile of activity and RQ predicted excursion in the AP direction, but only at the 50th and 25th activity percentiles. Since these effects are limited in number and inconsistent across outcomes and activity percentiles, it is difficult to draw firm conclusions regarding EMG's effects on the postural sway outcomes and the resultant indirect effects that might be occurring

through the EMG variables operating as mediators.

The fatiguing task had no significant relationships with the postural sway outcomes and predicted only the RQ muscle group activity at the 75th, 50th and 25th percentiles. No significant interactions of the fatiguing task variable were observed. The task that was performed significantly predicted all four of the postural sway outcomes, with the reach task invariably linked with greater sway. Task also was related to the EMG outcomes, particularly at the higher percentiles of activity; at lower percentiles differences between the reach and stationary tasks became attenuated and ultimately disappeared. (The number of muscle groups significantly affected by task declined from all 8 at the 95th and 75th percentiles of activity to 4 at the 50th percentile, 2 at the 25th and none at the 5th percentile.) Inclination was significantly related to postural sway, with greater inclinations being associated with greater sway (for sway area, length and M-L sway) implying that task performance on inclined surface increases postural instability. Inclination was also positively and significantly associated with EMG activity, with only three exceptions (LG and RG muscle groups' 75th percentile of activity and RG's 50th percentile of activity). However, presence of a visual cue was not associated with either postural sway or EMG activity, with only one significant relationship discovered (presence of a visual cue was associated with diminished sway length in the 25th percentile model of EMG activity only).

A few interactions among the experimental conditions were found to affect the postural sway and EMG outcomes. The task X inclination interaction was significantly related to all of the postural sway outcomes (in each of the 5 SEMs); sway was found to increase less (or even decline) during the reach task as the inclination angle increased from 0 to 26 degrees, relative to the stationary task. The task by inclination angle interaction was also found to significantly predict 2, 3, 0, 2 and 5 of the EMG muscle groups' activity at the 95th, 75th, 50th, 25th and 5th percentiles of activity, respectively. These interactions indicated that muscle activity tended to increase to a greater degree during the reach task as the inclination angle increased, particularly for the steepest angle (26 degrees). Finally, task was significantly interacted with presence of a visual cue for the postural sway outcome of excursion in the ML direction for all models except the SEM for the 95th percentile of EMG activity data. Presence of a visual cue was somewhat more beneficial in the reach condition, as compared to the stationary condition, which is an important finding for developing potential preventive techniques to minimize falls/near falls during reach task.

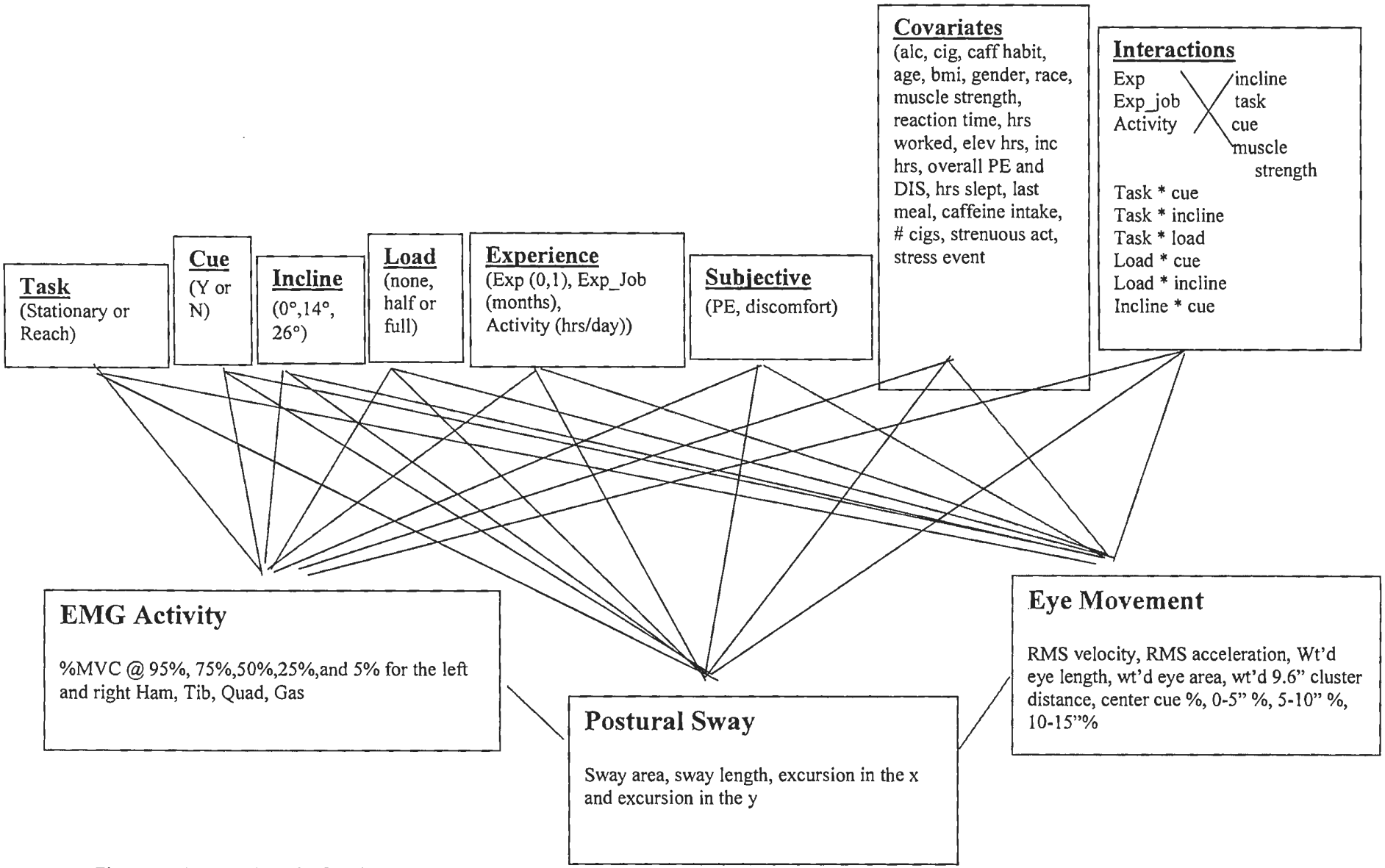


Figure 53. Structural Model for Phase 3:
EMG, sway and eye movement data analysis

D.3.4. ISCAN and Postural Sway Results and Discussion

All tables and figures for the eye movement variables and the postural sway can be seen in Appendix T. A similar analysis of eye movement and postural sway outcomes was completed as for the EMG and postural sway outcomes. Separate structural equation models (SEMs) were performed for each of four postural sway outcome measurements (area, length, and excursion in the medio-lateral (X) and anterior-posterior (Y) direction) and 9 eye movement measurements (RMS velocity, RMS acceleration, eye path length, eye path area, distance between clusters and the percent time spent on the center cue, 0-5 inches above and below the center cue, 5-10 inches above and below the center cue and 10-15 inches above and below the center cue). A schematic of the structural model design can be seen in figure 53. In the SEMs, the eye movement data were treated as mediator variables, i.e., affected by the other exogenous variables in the models but predictors of the postural sway outcomes. Three work experience variables: a dichotomous variable denoting work experience on inclined and/or elevated surfaces; a continuous variable representing the number of months of such work experience; and a continuous variable for the average number of hours of such work activities per week were tested in separate SEMs. Three loading variables were analyzed as exogenous factors: the fatiguing task that the worker performed during each trial, a trichotomous variable; the continuous Borg scale rated by the worker after each trial; and the continuous Bishop scale rated by each worker at each trial. In each of these analyses, the experimental conditions of task performed (reach vs. stationary), inclination angle (0, 14 or 26 degrees) and the presence of a visual cue (yes/no) were treated as exogenous variables. The interactions between the experience factor used in each model with load, task performed, inclination and cue were also tested for significance on the eye movement and postural sway outcomes. Other covariates (e.g., age, gender, height and muscle strength) were analyzed for statistical significance. The interaction between the experience factor used in each model and muscle strength also was included as an exogenous factor, primarily due to the observation that experienced workers tended to have greater muscle strength. Covariates and interactions that were not significant were removed from the statistical models in a backward elimination process. For the postural sway measurements, a one-tailed alpha of $p < 0.05$ was used as criteria if the covariate was in the expected direction based upon our experience from previous studies. For the eye movement variables, a two-tailed alpha of $p < 0.05$ was used. The work experience and experimental condition variables, including the trichotomous fatiguing task factor, were forced into each of the SEMs and their statistical significance evaluated in the final models that included only statistically significant covariates.

The p-values from the SEMs for the effects of work experience, load and the experimental conditions on each of the eye movement and postural sway outcomes, and for the effects of eye movement on sway are shown in Table T-1 in Appendix T. Since multiple models were run for each of the factors other than the experience variables, the range of the p-values from these models is tabled. The range of p-values was generally small, and in only one case did the multiple models analyzed for each of these factors differ in terms of their statistical significance on any of the eye movement or sway outcomes. One-tail p-values are shown for the

dichotomous factors of work experience, task and visual cue and the continuous predictors of the sway outcomes (i.e. years of work experience, hours of work activity, and the Borg and Bishop scales). Two-tail p-values are shown otherwise (i.e. for the trichotomous factors of the fatiguing task performed and the inclination factor) and for all predictors of the eye movement outcomes. The least square means (geometric means for the eye movement and sway data) for each of the categorical factors are shown in Table T-2 in Appendix T. The median least square mean from the multiple models analyzed is shown for the experimental conditions' main effects and for the interactions among the experimental conditions.

For the work experience variables, the dichotomous work experience (exp) model showed significant differences between the inexperienced and experienced subjects for nearly all the eye movement variables but none of the sway variables. For the RMS velocity, RMS acceleration, weighted eye length, weighted eye area and weighted cluster distance the inexperienced had higher values than the experienced. This would indicate that the inexperienced subjects tended to look around more during the trials. For the fixations on the center cue and directly above and below the center cue, the experienced had more fixations, although directly away from the center cue (0-5") was not significantly different. For fixations 5-10"and 10-15" away from the center, the inexperienced had more fixations, although for the 10-15" away fixations, the two groups were not significantly different. This indicates that experienced workers looked at and directly around the center cue more than the inexperienced workers, who tended to look further away from the cues. The interaction of experience and task was also significant for the RMS acceleration (see figure T-1a) with both the inexperienced and the experienced having greater acceleration for the reach task with the inexperienced being highest.

The months of work experience (exp_job) model showed experience as a predictor for RMS velocity, weighted eye length, center fixation percentage, weighted cluster distance, sway area and sway excursion in the medio-lateral direction. For the eye movement variables, the subjects with more months of experience have larger RMS velocities and more fixations on the center cue, but shorter eye movement lengths and cluster distances. This indicates the more experienced subjects looked around less and fixated more on the center cue. The interaction of months of work experience and task was also significant for the percent fixation 5-10" above the center cue and the weighted cluster distance (see figure T-1b) with more months having lower values and the stationary task decreasing more than the reach task with greater experience. This supports the indication that the subjects with more months experience look around less since the cluster distance is less and that the reach task requires both inexperienced and experienced to look around more. The interactions of months on the job and muscle strength of the quadriceps and hamstring were significant for RMS acceleration, and gastrocnemius for the weighted cluster distance. Experience was correlated with muscle strength so this would indicate that the stronger and more experienced subjects had more restricted eye movement patterns. Also, the sway parameter of sway area was significantly affected by the interaction of months on the job and muscle strength of the hamstring.

For the average number hours of work activity per week (activity) model, the eye length, eye area and center cue fixations and 0-5" away from the center cue decreased significantly as the hours of work activity increased but the RMS acceleration, however, significantly increased. This indicates the more experienced workers looked around less but the eye movement had a larger acceleration. For the sway parameters, the sway area and excursion in the medio-lateral and anterior-posterior direction are significantly decreased as the activity increased implying better postural balance for the more experienced subjects. The interactions of the hours worked and task were significant for the center cue fixation % and the weighted cluster distance (see figure T-1 c) with the same pattern of more hours worked decreasing the values and stationary task decreasing more than the reach task with increasing hours worked.

The fatiguing task was not significant in any model for any outcome measure. The task condition was significant for all eye and sway outcome measures except for the fixations in the center and 0-5" away from the center cue with the reach task being higher than the stationary task for every eye and sway variable.

The incline was a predictor of the RMS velocity, weighted eye length and all of the postural sway outcome measures. For the RMS velocity and the eye length, the 0° and 26° were higher than the 14° incline. For the center cue fixations, the highest percentage was at the 0° inclination and 0-5" around the center was highest at 14°. Figure T-2 (a-c) shows these results. For the sway variables, as the incline increased the sway area and length and excursion in the medio-lateral increased. The interaction of inclinations and task was significant for the weighted eye length (see figure T-3). The effect of inclination slightly decreased the reach task values and increased the stationary values of the eye length. Perhaps the subjects looked around less as the incline increased for the reach task to stabilize them during task performance. For the stationary task, the eye area is largest at 26° indicating that subject's used more of their visual field. This interaction was also significant for all four postural sway variables. For the sway area and excursion in the anterior posterior direction, the values decreased for the reach task and increased for the stationary task as the inclination increased This implies that subjects used more caution and therefore had increased postural stability during the reach task as the incline increased. For the stationary task, however, their postural stability decreased as the inclines increased. For the sway length and excursion in the medio-lateral direction the reach values increased as the inclination increased.

The visual cue was a predictor of several eye movement outcome measures. Figure T-4 (a-c) shows the effect of visual cues on the weighted eye area, weighted cluster distance and the fixations. For the eye area and cluster distance the visual cue decreased the value for all experience models (figure T-4 a and b) implying that the subjects utilized the visual cue when it was present. For the fixations (figure T-4 c), the value was higher when the visual cue was present for the center and directly around the center cue (0-5") and lower for the fixations further away from the cue, which is expected. This would indicate the subjects looked at or around the center cue when the visual cue was present and tended to look around more when the cue was

not present. The visual cue was also significant for the sway length with the length decreasing when the visual cue was present.

The interaction of visual cue and inclination was significant for the RMS velocity and acceleration (see Figure T-5 a and b) with the visual cue decreasing the values for the 0° and 26° inclinations. The interaction of visual cue and task was significant for the fixation percent on the center cue (see figure T-5 c) with a higher percent noted when the visual cues were present and the reach task having a higher percentage in conjunction with the presence of a visual cue. This implies that during the both the reach and stationary task, the subject's looked at the visual cue when it was present and even more during the reach task. The task and cue interaction was also significant for the sway excursion in the medio-lateral direction.

The eye movement variables had some effect on the sway outcome measures. Table T-3 shows the p-values for the significant variables. The fixation on the center cue percent and the RMS velocity was significant for the sway area variable. As the eye movement velocity increased the sway area increased and as the percentage of fixations on the center cue decreased the sway area increased. This implies that if the subject looked around more, the sway area was increased and postural instability increased. The sway length was predicted by the fixation percentage far from the center cue (10-15"). As the percentage of fixations 10-15" away from the center cue decreased the sway length increased. Since the center cue was oriented below eye level for the subjects, perhaps 10-15" above the cue was more at eye level and if the subjects looked directly forward their sway length decreased, increasing postural stability. The excursion in the medio-lateral direction was predicted by the percent fixations directly around the center cue (0-5") and the weighted cluster distance. The ML excursion increased as the percentage increased and as the cluster distance decreased. The excursion in the anterior-posterior direction was predicted by the percent fixation on 10-15" away from the center cue. The AP excursion increased as the percentage increased. This indicates as fixation percentages increased around the cue, both the AP and ML excursions increased, which could mean more postural instability.

D.3.5 Perceived Sense of Fall (PSOF) analysis

The p-values for the Phase III repeat measure ANOVA are shown in table 27. The least squares means for this analysis are shown in table 28. A subject can obtain a maximum PSOF score of 8 implying highest fear of loosing balance or fall and a minimum PSOF score of 0 implied no fear of loss of balance/fall. The cofactors that were significant are also shown in the table 27.

The main effect of task type and inclination produced significant effects on PSOF. The reach task produced a lower PSOF score than stationary task implying that workers perceived the reach task to be less threatening to their postural stability. This unexpected finding implies that since during reach task the workers were conducting a voluntary motion their perceived postural stability was less threatening than that for the stationary task, which produced more of a non-voluntary body sway. This subjective response of postural stability to task type is opposite to the

objective measure of postural stability. In other words the reach task always produced a higher response in objective measure of postural sway (measured by SA, SL and excursion values in the ML and AP directions) than that for the stationary task implying an increased postural instability. Therefore, there is a mismatch between subjective and objective responses of postural stability for the performance of two tasks. This type of mismatch may prove to be a reason for safety hazard due to potential fall or near fall event to occur. The inclination levels 0 degrees to 14 to 26 degrees produced a monotonically increasing scores of PSOF implying that workers perceived their postural stability to be increasingly threatened as the inclination increased. While placement of visual cue did not produce significant effect on the PSOF score the absolute values of PSOF was lower with the cue than without the cue implying that workers perceived the placement of cue produced a lesser threat to their postural stability. The main effects of work load and experienced did not produce significant effect on PSOF scores.

Three terms of interactions between incline and experience (defined three ways i.e., activity, experience category and experience in months) were significant. The interaction between incline and the experience term defined as EXP (categorical) showed that experienced workers rated 0 ° and 14° inclination with higher PSOF score than the inexperienced group while at 26 ° the response was opposite. Since 26° of inclination always produced highest objective measure of postural sway (SA, SL, ML and AP sway), it is not clear why experienced workers (as opposed to inexperienced) did not perceive the 26° threatening to their postural stability.

Table 27. P-value ranges for testing the effects of task, incline, cue, load, exp_job, activity, and experience variables on PSOF.

	Effect	*P-value range*
1	Task	**0.001 - 0.005**
2	Incline	**0.0001 (3)**
3	Cue	0.184 - 0.192
4	Load	0.639 - 0.670
5	Exp_job	0.198 (1)
6	Activity	0.386 (1)
7	Exp	0.449 (1)
8	Elev_hr	**0.013 - 0.040**
9	Hrs_slpt	**0.0001 (3)**
10	Hrs_lmeal	**0.0001 (3)**
11	Caffeine	**0.017 - 0.018**
12	Discomfort	**0.0001 (3)**
13	Muscle_t_avg	**0.022 - 0.023**
14	Exp_job*incline	**0.0001 (1)**
15	Activity*task	**0.017 (1)**
16	Activity*incline	**0.028 (1)**
17	Incline*exp	**0.028 (1)**

Table 28. Median Least Square Mean Values of PSOF

	Effect	*Mean*	*s.e.*
1	Task_reach	1.089	0.214
2	Task_stationary	1.219	0.213
3	Incline_0	0.774	0.215
4	Incline_14	1.022	0.215
5	Incline_26	1.682	0.216
6	Cue_no	1.179	0.214
7	Cue_yes	1.139	0.214
8	Load_full	1.074	0.136
9	Laod_half	1.113	0.135
10	Load_none	1.292	0.515
11	Exp_0	1.179	0.251
12	Exp_1	1.139	0.270
13	Caffeine_1	1.277	0.216
14	Caffeine_2	1.042	0.221
15	Inc*expo_00	0.742	0.255
16	Inc*expo_01	0.806	0.274
17	Inc*expo_140	1.005	0.253
18	Inc*expo_141	1.039	0.275
19	Inc*expo_260	1.789	0.256
20	Inc*expo_261	1.574	0.273

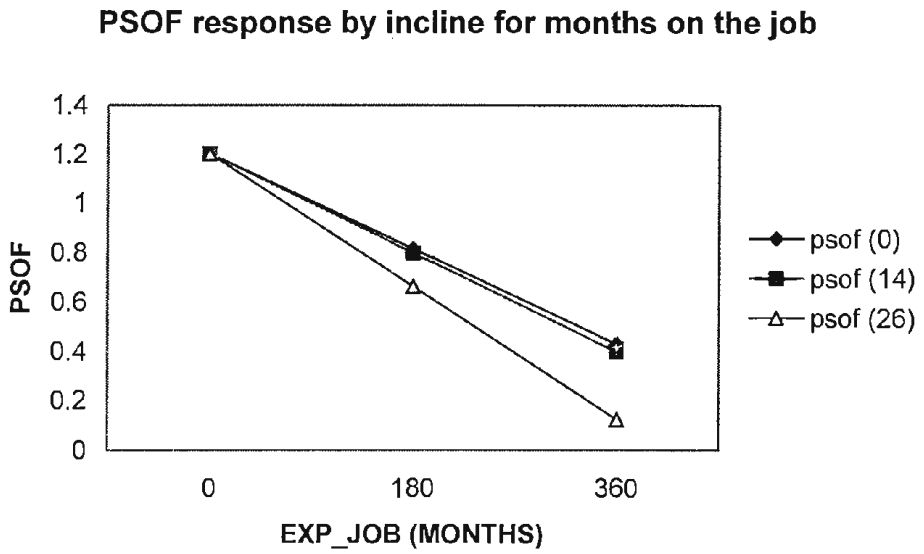


figure 54. PSOF by incline and months on the job (exp_job)

D.3.6. The Estimated Maximum Displacement Test (EMAX)

In the following section, the results of the EMAX test are given.

Displacement and Velocity of Center of Gravity

The video recordings were digitized at a rate of 60 Hz (each frame being 1/60 seconds apart). The time frames noted during digitization were:

1. Triggering of the synchronized system- the instant that the subject was told to start the task.
2. The first movement noted after the trigger.
3. The moment at which either of the heels or both heels left the ground
4. The moment when the first toe lifted off the ground as a step was taken
5. The moment when the first heel strike was made.
6. The moment when the second foot first left the platform.
7. The moment when the subject stood upright after the step, with both feet flat on the ground.

The Peak system was used to calculate the horizontal and vertical coordinates of the COG. The timing of each event and horizontal coordinates of the COG were recorded

The 6 digitization periods were established as follows:

Event 1: Trigger to first detected movement
Event 2: First detected movement to first heel off
Event 3: First heel off to first toe off
Event 4: First toe off to first heel strike
Event 5: First heel strike to second toe off
Event 6: Second toe off to end of task (after completing the whole step response, standing still off the platform).

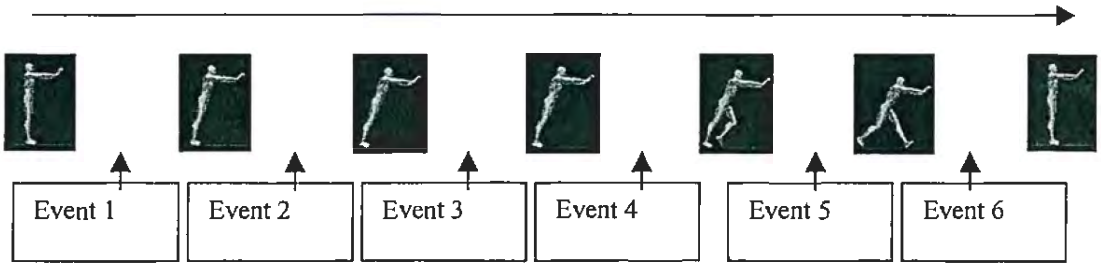


Figure 55. Schematic of Events

A t-test was used to compare the difference (if the variances were unequal) in experienced and inexperienced subjects for the center of gravity (COG) displacement and velocity for each event. The results are shown in tables 29 and 30. Subjects with experience took longer steps for every event and had faster speed for events 1 and 4.

Table 29. t-test results for comparing displacement (m) between inexperienced and experienced subjects

Displacement for Event:	Experienced	Mean (m)	p-value
1	No	0.7321	**0.0393**
	Yes	0.798	
2	No	0.8088	**0.0485**
	Yes	0.8733	
3	No	0.9661	**0.0168**
	Yes	1.0502	
4	No	1.1417	**0.0087**
	Yes	1.2383	
5	No	1.3117	**0.0066**
	Yes	1.4238	
6	No	1.4595	**0.0115**
	Yes	1.5802	

Table 30. t-test results for comparing velocity (m/s) between inexperienced and experienced subjects

Velocity for Event:	Experienced	Mean (m/s)	p-value
1	No	0.3379	**0.0155**
	Yes	2.5772	
2	No	0.712	0.3460
	Yes	0.6454	
3	No	6.5114	0.4604
	Yes	5.6756	
4	No	5.2746	**0.0014**
	Yes	6.1521	
5	No	12.611	0.5311
	Yes	12.028	
6	No	4.763	0.0783
	Yes	3.962	

Center of Pressure Displacement

A t-test was used to compare the difference in experienced and inexperienced subjects for the center of pressure (COP) displacement. The distance in centimeters in the anterior direction and in the resultant of anterior/left and anterior/right were averaged for three trials. See figure 55 for a description of these outcome measures. The results are shown in table 31. No significant differences were found between the experienced and inexperienced subjects although the

experienced subjects tended to travel further in the anterior direction before stepping off the plate.

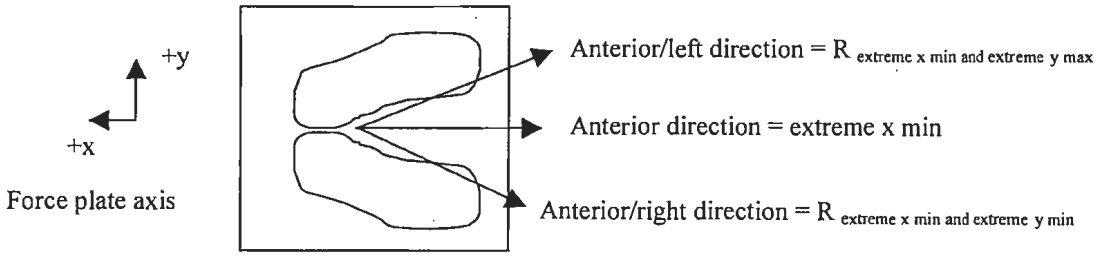


Figure 56. Outcome measures for Center of Pressure (COP) movement during the EMAX test.

Table 31. t-test results for comparing distance (cm) between inexperienced and experienced subjects

Variable:	Experienced	Mean (cm)	p-value
Anterior distance	No	7.875	0.58
	Yes	8.263	
Anterior/Left distance	No	12.283	0.27
	Yes	15.789	
Anterior/Right distance	No	9.6197	0.95
	Yes	9.5475	

EMG activity

A t-test was used to compare the difference of variances (unequal) in experienced and inexperienced subjects for the muscle activity for each event. The results are shown in table 32. The mean of three trials of the log percent of MVC of eight muscle groups was used for analysis. No significant differences were found except for the right quad in the 5th event.

Table 32. The geometric mean and p-values for each muscle group for the six intervals.

Muscle	Experience	Interval 1		Interval 2		Interval 3		Interval 4		Interval 5		Interval 6	
		GM	p-value	GM	p-value	GM	p-value	GM	p-value	GM	p-value	GM	p-value
Left Quad	no	1.08	0.55	1.13	0.81	1.47	0.29	1.76	0.66	1.65	0.60	1.70	0.61
	yes	1.09		1.14		1.66		1.85		1.75		1.62	
Left Ham	no	1.28	0.69	1.51	0.15	1.96	0.44	1.89	0.44	1.95	0.64	1.77	0.26
	yes	1.25		1.38		1.79		2.02		2.01		1.94	
Left Tib	no	1.12	0.58	1.14	0.58	1.55	0.94	1.80	0.22	1.98	0.65	1.72	0.09
	yes	1.09		1.17		1.56		1.73		2.11		1.94	
Left Gas	no	1.23	0.34	1.83	0.58	2.40	0.29	2.23	0.80	2.11	0.09	2.00	0.65
	yes	1.29		1.76		2.20		2.27		2.04		1.91	
Right Gas	no	1.21	0.77	1.72	0.24	2.35	0.41	2.36	0.26	2.11	0.71	2.08	0.51
	yes	1.19		1.55		2.19		2.06		1.96		1.95	
Right Tib	no	1.17	0.31	1.20	0.80	1.64	0.55	1.82	0.51	1.93	0.51	1.69	0.31
	yes	1.10		1.18		1.55		1.91		2.01		1.78	
Right Ham	no	1.39	0.71	1.63	0.90	1.83	0.62	1.97	0.79	1.82	0.53	1.78	0.08
	yes	1.44		1.65		1.91		1.93		2.20		2.01	
Right Quad	no	1.14	0.32	1.16	0.66	1.67	0.58	1.82	0.70	1.96	**0.01**	1.70	0.85
	yes	1.07		1.12		1.55		1.90		1.78		1.67	

Extension of current study

The following extension of the proposed study (M.S. Thesis by Jean Mangaraham) was completed and the findings are as follows:

The aim of this study is to measure the effects of muscular fatigue and work experience on patterns of movement during a forward falling task. Eleven subjects, 6 experienced and 5 inexperienced workers of elevated and/or inclined surfaces, participated in the study. The subjects were required to voluntarily fall forwards in a sagittal plane (Emax task). The Emax task was carried out before and after a fatiguing task of the lower limb musculature. To characterise pattern of movement, horizontal displacement and velocity of the center of gravity (COG) was measured by two-dimensional kinematic analysis. Electromyography (EMG) was utilised in synchrony, to describe the associated muscular activity levels of the left and right gastrocnemius, tibialis anterior, quadriceps and hamstrings muscles. A general linear model was utilised to carry out repeated measures analysis of covariance. Repeatability tests revealed that all independent variables, except for relative EMG levels of tibialis anterior of the initially weight bearing limb, did not vary significantly between trials. The results show that during an Emax task, if an individual's base of support is not restricted from being displaced forward by a step, then the COG could be displaced in a horizontal plane beyond the base of support, prior to the first detection of a stepping motion (heel rise). The COG displacement during an Emax task was significantly less after fatigue of the lower limbs ($F=5.14$, $p=0.05$; non-fatigued mean = 0.1653m, fatigued mean = 0.1555m). These results support past studies, which suggest that

fatigue of the lower limb musculature increases co-contraction around the joints, reducing sway and step length. Experienced workers had higher relative electrical activity of the hamstrings muscle of the stepping limb, especially during terminal swing, compared to inexperienced workers ($F=5.58$; $p=0.05$). These results show that experienced workers have more appropriate muscle activity during an Emax task, as it is usually expected that high hamstring eccentric activity occurs in the stepping limb during terminal swing to decelerate the swinging limb. The results from the current study suggest that training workers in high-risk fall environments should not be limited to education and personal protective equipment alone, but should also include the implementation of occupational specific physical exercises [46].

D.3.7. Effect of experience, physical load, task, inclination, visual cues on indices of postural stability (Whole body C.G. based Kinematic outcomes and CP based outcomes)

All tables and figures for the results of the analysis with indices of postural stability are given in Appendix U. The video data was digitized to obtain three dimensional whole body center of gravity (CG) motion (kinematic data) associated with tasks performed in the Phase-III. Based on the CG data, custom software (IPSB software developed in our laboratory) was used to obtain the postural stability indices of WRTI and minimum IPSB. During each task, the video data was also digitized to obtain the stability boundary defined by the shoe marker system defined earlier in this report. The IPSB, SAR and WRTI were also calculated with CP based data. As per the definition of IPSB given earlier in this report, the lower the value of IPSB, the closer is the location of the whole body CG or CP to the subjects' stability boundary implying increase in postural instability. A lower value of stability boundary implies smaller base of support available for the whole body CG or CP to project in the horizontal plane, which might give rise to postural instability. In other words, a lower IPSB and a lower stability boundary imply that the subject's postural stability is jeopardized. On the other hand, a higher value of SAR and WRTI implies poorer postural stability. Three IPSB variables were used i.e., Average IPSB, Maximum IPSB and Maximum IPSB.

ANCOVA (Analysis of Covariance) was performed to analyze the data. The between subject covariates were the same as those used for other analyses presented earlier in this report. These covariates were the between-subject variables used to predict the postural sway/stability outcomes. Within-subject, the experimental conditions of experience (three variables were used to define experience: EXP categorical, EXP_Job months on the job and number of Activities involving inclined and elevated surfaces) inclination, physical work load,, task and visual cues were tested for their effect on postural stability. In addition, all possible two-factor interactions between the within-subject factors were investigated. The postural sway data were analyzed within the two tasks performed by the subjects (Reach and Stationary tasks). Beginning from the saturated models involving all covariates, within-subject factors and interactions, final models were derived through a backward elimination strategy of insignificant covariates and two-factor interactions. In the final models, only significant covariates and two-factor interactions were included, along with the within-subject main effects, which were always included in the

ANCOVA models. A total of 36 models were tested. An alpha-level of 0.05 was used for all statistical tests.

The results of the ANOCOVA are shown in Tables U-1 and U-2 in Appendix U. The means for the levels of each within-subject factor are shown in Tables U-3 and U-4 in Appendix U. Task was significant for 30 out of 36 models i.e. Reach task (highest SAR and WRTI) produced significant postural instability in comparison to the Stationary task (smallest SAR and WRTI). Inclination factor was significant for 35 out of 36 models. Only 5 models showed significant effects of placement of cue on postural stability indices. Only 6 models of experience variable defined as categorical variable of EXP were significant implying that experienced workers showed a higher (implying better balance) value of IPSB compared to that of an inexperienced one. Not all stability variables showed significant effect for experience factor. In general the variables of SAR and WRTI showed increased values for Reach task compared to that for Stationary task implying the former task type is detrimental to postural stability. There were 24 significant models for interaction term of Task X Inclination. In general Reach and Stationary tasks when performed at 14 and 26 degrees inclined surfaces the WRTI and SAR values were significantly higher than that at 0 degree or flat surface implying poorer balance in the former case. The IPSB variable did not show consistent results regarding Task X Inclination effects. There were two models (outcome variables of Min IPSB based on CG and Log WRTI based on CG) showing significant interactions for Activity on inclined/elevated surface (one of the variables of experience) X inclination. Figure U-A shows a plot of Log WRTI (CG based) versus Activity on inclined/elevated surface (one of the experience variables) for three inclined surfaces. In Figure U-A shows that with increasing experience the Log WRTI value decreased for all three inclined surfaces implying that increase in experience is associated with lesser amount of postural instability while performing task on inclined surfaces. Also the postural instability was highest (as depicted by a higher value of Log WRTI) for task performance on 26 degree inclined surface compared to both 0 and 14 degrees. Similar increase in postural instability as depicted by decrease in Min IPSB (CG based) for 26 degree was also observed in comparison to 0 and 14 degree inclination (Figure U-B). There were two models showing significant interactions for two of the experience variables (EXP_Job in months and Activities on inclined/elevated surface in hours per week) X task type. In Figures U-C and U-D it can be seen that workers with increasing experience showed lesser amount of postural instability (as depicted by increasing CG based Max IPSB and decreasing value of Log WRTI) while performing either Stationary or Reach task. Similarly, for the task effect both the variables showed that in comparison to Stationary task the Reach task caused an increased level of postural instability (Figures U-C and U-D).

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Appendix A

Consent Forms

Modified Informed Consent (for Experiment-1)

Effect of Workload on Task Performance on Inclined Surfaces

I. Introductory Paragraph

Before agreeing to participate in this study, it is important that the following explanation of the proposed procedures be read and understood. It describes the purpose, procedures, benefits, risks and discomforts, and precautions of the study. It also describes alternative procedures available and the right to withdraw from the study at any time. It is important to understand that no guarantee or assurance can be made as to the results. It is also understood that refusal to participate in this study will not influence standard treatment for the subject.

II. Objectives of the Study

I, _____, agree to participate in a research study, the purpose of which is to measure changes in my ability to detect orientations of vertical and horizontal visual cues after performing different workloads.

III. Procedures

If I choose to participate in this study, I can expect to perform the following procedures:

a. First the investigators will describe the details of the study to me and the tasks I will be asked to perform.

b. Next I will be given a physical evaluation by a physician who will ask questions concerning my medical history, as well as my work history. The examination results will be used to determine my ability to perform the tests.

c. I will be given a list of testing dates/sessions for all testing sessions. I will abstain from alcohol for at least forty eight(48)hours prior to testing. Also, I will abstain from tobacco and caffeine for at least twelve(12) hours prior to testing. I will wear custom designed clothing provided by the investigator.

d. Next, my muscle strength relevant for my postural balance will be measured with a noninvasive sensor called load cell. Also, noninvasive surface electrodes will be attached to my skin (with a tape) at several locations on my leg for measuring my muscles' contraction patterns. Also, my reaction time will be measured by responding to light cues.

e. Next, I will perform the test of voluntary maximal reach. During the test, I will be asked to stand on ground on a force platform with my feet in a heels-together stance, and asked to slowly reach forward to push a foam board hanging at shoulder height until, I have to take a step in the forward direction.

f. On the day of testing, the investigator will place a noninvasive heart rate monitor across my chest to continuously monitor my heart rate. I will also wear a pair of regular shoes provided by the investigator. I will stand on inclined surfaces in a room with no light. Next, I will be presented with a series of visual cues of varying inclinations on a projection screen. I will be asked to determine whether the projected visual cue is vertical or horizontal. The specific details of this test will be explained to me before initiating the test. This test may take up to three (3) hours. If there is any significant variance from the stated time period, I will be notified.

g. Next, I will sit on a chair for approximately five (5) minutes so that my normal sitting heart rate can be recorded.

h. Next I will be asked to maintain a sustained static posture for about four (4) minutes. I will be asked to complete a task at a table in front of me during this time.

I. The tests described in item h will be repeated about six (6) times during the testing session with sufficient rest periods.

j. I understand that, depending on the availability of funding, I will be paid about $300 total for participating in this project.

IV. Risks and Precautions

I understand that there exists the possibility of certain changes occurring in my body during the test. They include irregular breathing, abnormal blood pressure, heart beat, and in rare instances heart attack, skin abrasions and localized skin sensitivity to electrodes/tapes. Every effort will be made to minimize these through the screening examination of my physical and health history, and by observation during the test. Trained personnel will also be available to deal with any unusual situations which may arise. I understand that during the study there might be a chance of me falling down. I will be wearing a safety harness; impact resistant pads will be placed around the test area and observers will be near me at all times to secure against this remote possibility of falling.

After completion of the testing, I may experience some localized muscle discomfort for up to several days after the experiment depending on my physical fitness.

V. Pregnancy

If I am a woman of childbearing potential, I will not participate in this research study unless I have a negative pregnancy test and, with the investigator's knowledge and approval, I am employing a form of birth control approved by a physician and/or the investigator directing this study. I agree to inform the investigator immediately if: 1) I have any reason to suspect that I am pregnant; 2) I find that circumstances have changed and that there is now risk of me becoming pregnant; or 3) I have stopped using the approved form of birth control.

VI. Marketable Tissue/Material

Not Applicable

VII. Confidentiality of Records

The identity of all subjects will be kept confidential. The data will be analyzed by the investigators only and kept in a safe and secure place. If any of the data are published in scientific journals, subject names or initials will not be used. It is possible that authorized persons from the funding agency may request access to subject's record.

VIII. Availability of Information

Any questions that I might have concerning any aspect of this investigation will be answered by Dr. Amit Bhattacharya (558-0503) and/or his associates.

IX. Compensation

The University of Cincinnati Medical Center follows a policy of making all decisions concerning compensation and medical treatment for injuries occurring during, or caused by participation in, biomedical or behavioral research on an individual basis. If I believe I have been injured as a result of research, I will contact Dr. Amit Bhattacharya (558-0503) or Dr. Harry Rudney (558-5259), chairperson of University of Cincinnati Medical Center Institutional Review Board.

X. Fiscal Responsibility

Funds are not available to cover the costs of any ongoing medical care, and I remain responsible for the cost of nonresearch-related care. Tests and studies done solely for the purposes of research will be paid for from research funds and I should not be billed for them. If I have questions about my medical bill relative to research participation, I may contact Dr. Amit Bhattacharya (558-0503).

XI. The Right to Withdraw

I am free to withdraw from this investigation at any time. Should I wish to withdraw, I have been assured that standard therapy for my condition will remain available to me. I have been informed of the probable consequences of my withdrawal from the study.

XII. Is the subject participating in another study?

☐ Yes. If yes, please provide the principal investigator's name and title of the study.

☐ No.

XIII. Witnessing and Signatures ☐

CHECK BOX IF VERBAL ASSENT OBTAINED BY INVESTIGATOR

_____

Subject's Signature Date

_____

Legal Representative/Parent Date

_____

Investigator Date

_____

Witness Date

Modified Informed Consent (for Experiment-2)

Effect of Workload on Task Performance on Inclined Surfaces

I. Introductory Paragraph

Before agreeing to participate in this study, it is important that the following explanation of the proposed procedures be read and understood. It describes the purpose, procedures, benefits, risks and discomforts, and precautions of the study. It also describes alternative procedures available and the right to withdraw from the study at any time. It is important to understand that no guarantee or assurance can be made as to the results. It is also understood that refusal to participate in this study will not influence standard treatment for the subject.

II. Objectives of the Study

I, _____, agree to participate in a research study, the purpose of which is to determine how my eye movements scan my surroundings, and how my postural muscles contract while standing/working on an inclined surface in good light and in poor light immediately after performing physical workload.

III. Procedures

If I choose to participate in this study, I can expect to perform the following procedures:

a. First the investigators will describe the details of the study to me and the tasks I will be asked to perform.

b. Next I will be given a physical evaluation by a physician who will ask questions concerning my medical history, as well as my work history. The examination results will be used to determine my ability to perform the tests.

c. I will be given a list of test dates for all testing sessions. I will abstain from alcohol for at least forty-eight (48) hours prior to testing. Also, I will abstain from tobacco and caffeine for at least twelve (12) hours prior to testing. During testing sessions I will wear custom designed clothing, shoes, and reflective markers provided by the investigator, which

will allow assessment of body segment movements.

d. Next, my muscle strength relevant for my postural balance will be measured with a noninvasive sensor called load cell. During this test, non-invasive surface electrodes will be attached (with a tape) to my skin for the measurement of muscle contractions from my leg muscles. Also, my reaction time will be measured by responding to light cues. My vision will be tested with a standard vision tester comparable to the one used for Driver's License Test.

e. Next, I will perform the test of voluntary maximal reach. During the test, I will be asked to stand on the ground on a force platform, and asked to slowly reach forward to push a foam board hanging at shoulder height until, I have to take a step in the forward direction. I will be given several practice sessions. The entire test session will be videotaped to measure my body segment movement patterns during the test. Total time required for this test will be about twenty (20) minutes.

f. Other tests will be performed in the laboratory while standing in front of a black display panel. A test will consist of evaluation of my eye movement patterns and my postural balance while standing on: 1) inclined surfaces, and 2) in well- and poorly-illuminated environments. I will be tested under all possible combinations of Conditions 1 and 2. There will be at least a one (1) day interval between subsequent tests. I will be given prior instructions regarding the details of the protocol.

g. On the day of testing, the investigator will place a noninvasive heart rate monitor across my chest to continuously monitor my heart rate. I will wear a head band which will have noninvasive sensors to monitor my eye movement patterns. My body segment movements will be recorded with a video camera system. Also, noninvasive surface electrodes will be attached to my skin (with a tape) at several locations on my leg for measuring my muscles' contraction patterns. The order of presenting the testing conditions described in Item III.f. will be chosen randomly by the investigator.

h. I will sit on a chair for approximately fifteen (15) minutes so that my normal sitting heart rate can be recorded.

i. Next, I will be asked to stand upright, relaxed, with my eyes open on the force platform for thirty (30) seconds. An outline of my feet will be made. This

platform will noninvasively monitor changes in my body movement. At the end of the test, I will be asked to rate my perceived sense of body motion.

j. I will again stand on the force platform. Next, I will be asked to reach for a 5 lb. weight placed on my right side, lift it, and then lower it to a shelf on my left side. This lifting/lowering cycle will be repeated four times. At the end of the test, I will be asked to rate my perceived sense of body motion. This test will take about thirty (30) seconds.

k. I will then be asked to sit comfortably and relax until my heart rate returns to normal resting levels.

l. Next, I will be asked to maintain a sustained static posture for about four (4) minutes. I will be asked to complete a task at a table in front of me during this time.

m. The tests described in item l. will be repeated about six (6) times during the testing session with sufficient rest periods.

n. Next, I will repeat Items f. through l. for various combinations of treatment Conditions 1 and 2 described in Item III.f.

o. On another day, the above procedures will be repeated with different combinations of various surface conditions and environmental lighting conditions described in Item III.f. Each testing day will take about three (3) hours of my time. If there is any significant variance from the stated time period, I will be notified.

p. I understand that I will be paid about $300 total for participating in this project.

IV. Risks and Precautions

I understand that there exists the possibility of certain changes occurring in my body during the test. They include irregular breathing, abnormal blood pressure, heart beat, and in rare instances heart attack. Every effort will be made to minimize these through the screening examination of my physical and health history, and by observations during the test. Trained personnel will also be available to deal with any unusual situations which may arise. I understand that during the study there might be a chance of me falling down. I will be wearing a safety harness; impact resistant pads will be placed around the test area and observers will

be near me at all times to secure against this remote possibility of falling.

After completion of the testing, I may experience some localized muscle discomfort for up to several days after the experiment depending on my physical fitness.

V. Pregnancy

If I am a woman of childbearing potential, I will not participate in this research study unless I have a negative pregnancy test and, with the investigator's knowledge and approval, I am employing a form of birth control approved by a physician and/or the investigator directing this study. I agree to inform the investigator immediately if: 1) I have any reason to suspect that I am pregnant; 2) I find that circumstances have changed and that there is now risk of me becoming pregnant; or 3) I have stopped using the approved form of birth control.

VI. Marketable Tissue/Material

Not Applicable

VII. Confidentiality of Records

The identity of all subjects will be kept confidential. The data will be analyzed by the investigators only and kept in a safe and secure place. If any of the data are published in scientific journals, subject names or initials will not be used. It is possible that authorized persons from the funding agency may request access to subject's record.

VIII. Availability of Information

Any questions that I might have concerning any aspect of this investigation will be answered by Dr. Amit Bhattacharya (558-0503) and/or his associates.

IX. Compensation

The University of Cincinnati Medical Center follows a policy of making all decisions concerning compensation and medical treatment for injuries occurring during, or caused by participation in, biomedical or behavioral research on an individual basis. If I believe I have been injured as a result of research, I will contact Dr. Amit Bhattacharya (558-0503) or Dr. Harry Rudney (558-5259), chairperson of University of Cincinnati Medical Center Institutional Review

Board.

X. Fiscal Responsibility

Funds are not available to cover the costs of any ongoing medical care, and I remain responsible for the cost of nonresearch-related care. Tests and studies done solely for the purposes of research will be paid for from research funds and I should not be billed for them. If I have questions about my medical bill relative to research participation, I may contact Dr. Amit Bhattacharya (558-0503).

XI. The Right to Withdraw

I am free to withdraw from this investigation at any time. Should I wish to withdraw, I have been assured that standard therapy for my condition will remain available to me. I have been informed of the probable consequences of my withdrawal from the study.

XII. Is the subject participating in another study?

☐ Yes. If yes, please provide the principal investigator's name and title of the study.

☐ No.

XIII. Witnessing and Signatures

☐ CHECK BOX IF VERBAL ASSENT OBTAINED BY INVESTIGATOR

_____
Subject's Signature Date

_____
Legal Representative/Parent Date

_____
Investigator Date

_____
Witness Date

Modified Informed Consent (for Experiment-3)

Effect of Workload on Task Performance on Inclined Surfaces

I. Introductory Paragraph

Before agreeing to participate in this study, it is important that the following explanation of the proposed procedures be read and understood. It describes the purpose, procedures, benefits, risks and discomforts, and precautions of the study. It also describes alternative procedures available and the right to withdraw from the study at any time. It is important to understand that no guarantee or assurance can be made as to the results. it is also understood that refusal to participate in this study will not influence standard treatment for the subject.

II. Objectives of the Study

I,_____,agree to participate in a research study, the purpose of which is to determine how my eye movements scan my surroundings, and how my postural muscles contract while standing/working on an inclined surface in good light and in poor light immediately after performing physical workload.

III. Procedures

If I choose to participate in this study, I can expect to perform the following procedures

a. First the investigators will describe the details of the study to me and the tasks I will be asked to perform.

b. Next I will be given a physical evaluation by a physician who will ask questions concerning my medical history, as well as my work history. The examination results will be used to determine my ability to perform the tests.

c. I will be given a list of test dates for all testing sessions. I will abstain from alcohol for at least forty-eight (48) hours prior to testing. Also, I will abstain from tobacco and caffeine for at least twelve (12)hours prior to testing. During testing sessions I will wear custom designed clothing, shoes, and reflective markers provided by the investigator, which will allow assessment of body segment movements.

d. Next, my muscle strength relevant for my postural balance will be measured with a noninvasive sensor called load cell.

During this test, noninvasive surface electrodes will be attached (with tape) to my skin for the measurement of muscle contractions from my leg muscles. Also, my reaction time will be measured by responding to light cues. My vision will be tested with a standard vision tester comparable to the one used for Drivers's License Test.

e. Next, I will perform the test of voluntary maximal reach. During the test, I will be asked to stand on the ground on a force platform, and asked to slowly reach forward to push a foam board hanging at shoulder height until, I have to take a step In the forward direction. I will be given several practice sessions. The entire test session will be videotaped to measure my body segment: movement patterns during the test. Total time required for this test will be about twenty (20) minutes.

f. Other tests will be performed in the laboratory while standing in front of a black display panel. A test will consist of evaluation of my eye movement patterns and my postural balance while standing on: 1) Inclined surfaces, and 2) In well and poorly-illuminated environments. I will be tested under all possible combinations of Conditions 1 and 2. There will be at: least a one (1) day interval between subsequent tests. I will be given prior instructions regarding the details of the protocol.

g. On the day of testing, the investigator will monitor my heart rate throughout the testing session by taking a standard radial pulse at specific intervals. I will wear a head band which will have noninvasive sensors to monitor my eye movement patterns. My body segment movements will be recorded with a video camera system, Also, noninvasive surface electrodes will be attached to my skin (with tape) at several locations on my legs for measuring my muscles' contraction patterns. The order of presenting the testing conditions described in Item III.f. will be chosen randomly by the investigator.

h. I will sit on a chair for approximately fifteen (15) minutes so that my normal sitting heart rate can be recorded.

I. Next, I will be asked to stand upright, relaxed, with my eyes open on the force platform for thirty (30) seconds that will noninvasively monitor changes in my body movement. At the end of the test, I will be asked to rate my perceived sense of body motion. .

I will again stand on the force platform. Next, I will be asked to reach for a 5 lb. weight placed on a shelf in front of me at waist height, lift it, and then lower it

back on to the shelf. This lifting/lowering cycle will be repeated four times. At the end of the test, I will be asked to rate my perceived sense of body motion. This test will take about thirty (30) seconds.

k. I will then be asked to sit comfortably and relax until my heart rate returns to normal resting levels.

1. Next, I will be asked to maintain a sustained static posture for about four (4) minutes. I will be asked to complete a task at a table in front of me during this time.

m. The tests described in item 1. will be repeated about *six* (6) times during the testing session with sufficient rest periods.

n. Next, I will repeat Items f. through 1. for various combinations of treatment Conditions I and 2 described in Item III-F.

o. On another day, the above procedures will be repeated with different combinations of various surface conditions and environmental lighting conditions described in Item III.F. Each testing day will take about three (3) hours of my time. If there is any significant variance from the stated time period, I will be notified.

p. I understand that I will be paid about $300 total for participating in this project.

IV Risks and Precautions

I understand that there exists the possibility of certain changes occurring in my body during the test. They include irregular breathing, abnormal blood pressure, heart beat, and in rare instances heart attack. Every effort will be made to minimize these through the screening examination of my physical and health history, and by observations during the test. Trained personnel will also be available to deal with any unusual situations which may arise. I understand that during the study there might be a chance of me falling down. I will be wearing a safety harness; impact resistant pads will be placed around the test area and observers will be near me at all times to secure against this remote possibility of falling.

After completion of the testing, I may experience some localized muscle discomfort for up to several days after the experiment depending on my physical fitness.

V Pregnancy

If I am a woman of childbearing potential, I will not participate in this research study unless I have a negative pregnancy test and, with the investigators's knowledge and approval, I am employing a form of birth control approved -by a physician and/or the investigator directing this study. I agree to inform the investigator immediately if: 1) I have any reason to suspect that I am pregnant; 2) I find that circumstances have changed and that there is now risk of me becoming pregnant; or 3) I have stopped using the approved form of birth control.

VI Marketable Tissue/Material

Not Applicable

VII Confidentiality of Records

The identity of all subjects will be kept confidential. The data will be analyzed by the investigators only and kept in a safe and secure place. If any of the data are published in scientific journals, subject names or initials will not be used. It is possible that authorized persons from the funding agency may request access to subject's record.

VIII Availability of Information

Any questions that I might have concerning any aspect of this investigation will be answered by Dr. Amit Bhattacharya (558-0503) and/or his associates.

IX Compensation

The University of Cincinnati Medical Center follows a policy of making all decisions concerning compensation and medical treatment for injuries occurring during, or caused by participation in, biomedical or behavioral research on an individual basis. If I believe I have been injured as a result of research, I will contact Dr. Amit Bhattacharya (558-0503) or Dr. Harry Rudney (558-5259), chairperson of University of Cincinnati Medical Center Institutional Review Board.

X Fiscal Responsibility

Funds are not available to cover the costs of any ongoing medical care, and I remain responsible for the cost of nonresearch-related care. Tests and studies done solely for the purposes of research will be paid for from research funds and I should not be billed for them. If I have questions about my medical bill relative to research participation, I may contact Dr. Amit Bhattacharya (558-0503).

XI The Right to Withdraw

I am free to withdraw from this investigation at any time. Should I wish to withdraw, I have been assured that standard therapy for my condition will remain available to me. I have been informed of the probable consequences of my withdrawal from the study.

XII Is the subject participating in another study?

☐ Yes.If yes, please provide the principal investigator's name and title of the study.

☐ No.

☐ CHECK BOX IF VERBAL ASSENT OBTAINED BY INVESTIGATOR

XIII. Witnessing and Signatures

_____
Subject's Signature Date

_____
Legal Representative/Parent Date

_____
Investigator Date

_____
Witness Date

PI: Dr Bhattacharya
PROTOCOL NO. 95-5-11-2
RECEIVED 5-15-00
REVISED
APPROVED 5-24-00
EXPIRES ON 5-24-01

Appendix B

Telephone History

Workers Employment History Telephone Interview

Date_____

Name_____Address_____City_____

State_____Zip_____ Phone#_____BD_____ Gender_____

1. Have you ever worked as a roofer? yes or no

2. Have you ever worked on elevated and/or inclined surfaces such as: ladders, scaffolds, dock ramps, etc? yes or no

***if no to 1 & 2 stop here, if 1 no & 2 yes, proceed to interview section "Other Surface Workers"**

3. Are your *currently* employed as a roofer? yes or no

a.) How long have you been continuously employed as a roofer? weeks months years #_____

****if no proceed to question # 9**

4. As a roofer, how many employers have you worked for? #_____

Employer_____Address_____ Phone #_____

Employer_____Address_____ Phone #_____

5. How often does your job involve being on a roof? a.) # hours/day _____

b.) #days/week_____

6. When you are not working as a roofer, what type of work do you do?_____

7. As a roofer did you receive any formal training in an apprenticeship school? yes or no

a.) How long did your training last? weeks months years #_____

8. If you had no formal training how long was "on the job" training? weeks months years #_____

**** continue only if yes to# 1 and no to #3**

9. When did you stop working as a roofer? month/year_____/_____

a.)How long did you work as a roofer? weeks months years #_____

10. If you are no longer working as a roofer why did you leave that job?
    a.) I thought it was too dangerous
    b.) My family thought it was too dangerous
    c.) Pay was not good
    d.) Got a different job
    e.) My health interfered with my roofers job
    f.) Having difficulty with managers/supervisors
    g.) I was injured as a result of roofing work
    h.) other (specify)_____

" Other Surface Workers Interview"

11. Are your currently employed at a job where you work on elevated and/inclined surface? yes or no

Specify which surface/surfaces_____

12. How long have you been continuously employed at this type or job? weeks months years #_____

13. As this type of worker how many employers have you worked for? #_____

Employer_____Address_____ Phone #_____

Employer_____Address_____ Phone #_____

14. How often does your job involve being on a this type of surface? a.) #hours/day _____

b.) # days/week _____

Appendix C

Preliminary Questionnaire

NAME:_____DATE:_____ID:_____

SSN: _____ TELEPHONE: _____

SEX: Female ____ Male ____ BIRTHDATE: _____

EDUCATION:(circle one) 1=less than 12th 2=high school grad

3=undergraduate degree 4=graduate degree

RACE (Please Circle NUMBER):

WHITE.....1

BLACK/AFRICAN AMERICAN.....2

HISPANIC.....3

NATIVE AMERICAN OR ALASKAN NATIVE.....4

ASIAN OR PACIFIC ISLANDER.....5

OTHER.....6

EMPLOYER_____

OCCUPATION:_____Shift:_____

JOB DUTIES: _____

ARE YOU CURRENTLY EXPOSED TO ANY OF THE FOLLOWING ON YOUR JOB? (Please Circle)

0. None 1.Solvents	5. Arsenic	9. Acrylamide
2. Lead	6. Kerosene/Mineral Spirits	10. Pesticides
3. Tolune	7. Perchloroethylene	11Combination
4. Styrene	8. Trichloroethylene	

DID YOU EVER HAVE A JOB IN ANY OF THE FOLLOWING INDUSTRIES FOR MORE THAN ONE YEAR?

0. None 1.Rubber/Tire Manufacture	5. Commercial Painting	9. Printing
2. Chemical or Paint Manufacture	6. Foundry	10. Lead Industry
3. Petroleum Refining	7. Dry Cleaning	11. Sand Blasting
4. Smelting Industry	8. Battery Plant (Lead or Storage)	12.Combination

HOBBIES (circle all which apply):

0. None 1.Stained Glass Work	7.Paint Removal	10.Pottery/Ceramic
2.Mimeographing	8.Silk Screening	11.Making Bullets
3.House Painting	9.Furniture Finishing	12.Indoor firing range
4.Melting Metal for any purpose	13.Cutting wood with Chain Saw	
5.Model Plane/Car Building	14. Combination	
6. Jewelry Making		

MEDICAL CONDITIONS (list all):

_____

_____

CURRENT MEDICATIONS

	Name of Medication	How Much?	How Often?
Prescription			

	Name of Medication	How Much?	How Often?
Non-Prescription *(For instance: cold remedies, decongestants, minor pain medications, and others.)*			

ALCOHOL

Do you now (within the last month) drink alcoholic beverages? Y N

If no, did you ever drink alcoholic beverages (more than one glass of beer, wine, or mixed drink per month)? Y N

How old were you when you first started drinking alcoholic beverages? ____

If you stopped drinking alcoholic beverages completely, how old were you when you stopped? ____

About how often do/did you drink some kind of alcoholic beverage? (Chose ONE answer)

(Circle One)
1. Almost every day ____
2. Three or four times a week ____
3. Once or twice a week ____
4. Once or twice a month ____
5. Less than once a month ____

Based on the average of the entire time you drank alcoholic beverages, how often did you drink? (Chose ONE answer)

(Circle One)
1. Daily ____
2. Weekly ____
3. Monthly ____

Enter the number of drinks you consumed(per day, week, or month depending on how you answered the above question) ____

How many caffeinated drinks per day do you consume? ____

How many cigarettes do you smoke per day? ____

THE FOLLOWING IS A LISTING OF HEALTH PROBLEMS WITH WHICH YOU MAY HAVE HAD TROUBLE.

IF YOU HAVE HAD THIS PROBLEM AT ANY TIME, CIRCLE "Y" IN THE "EVER" COLUMN. ALSO WRITE THE *MONTH AND YEAR* WHEN THE PROBLEM *LAST OCCURRED*.
IF YOU HAVE NEVER HAD THIS PROBLEM, PLEASE CIRCLE "N" UNDER "EVER".

IF YOU ARE HAVING THIS PROBLEM RIGHT NOW, CIRCLE "Y" UNDER "CURRENT".
IF YOU ARE NOT HAVING THIS PROBLEM CURRENTLY, PLEASE CIRCLE "N" IN THE "CURRENT" COLUMN.

PROBLEM	EVER	CURRENT	MONTH/YEAR LAST EPISODE
Problems with vision	Y / N	Y / N	_____
Shortness of breath with exercise	Y / N	Y / N	_____
Weakness in legs	Y / N	Y / N	_____
Numbness in legs	Y / N	Y / N	_____
Seizures, fits or convulsions	Y / N	Y / N	_____
Stroke	Y / N	Y / N	_____
Sudden blackouts	Y / N	Y / N	_____
Chronic or recurring spinning dizziness	Y / N	Y / N	_____
Chronic or recurring light-headedness	Y / N	Y / N	_____
Meniere's disease	Y / N	Y / N	_____
Problems with maintaining balance	Y / N	Y / N	_____
Parkinson's disease	Y / N	Y / N	_____
Multiple sclerosis	Y / N	Y / N	_____
Intermittent claudication (poor circulation in the legs)	Y / N	Y / N	_____
Anemia	Y / N	Y / N	_____
Chronic lung disease (emphysema or bronchitis, for instance)	Y / N	Y / N	_____
Heart disease	Y / N	Y / N	_____
Abnormal heart rhythm	Y / N	Y / N	_____
Heart attack	Y / N	Y / N	_____
Angina	Y / N	Y / N	_____
Congestive heart failure	Y / N	Y / N	_____
High blood pressure	Y / N	Y / N	_____
Chest pain	Y / N	Y / N	_____
Alcoholism or alcohol abuse	Y / N	Y / N	_____
Drug addiction or abuse	Y / N	Y / N	_____
Chronic foot or leg disability	Y / N	Y / N	_____

PROBLEM	EVER	CURRENT	MONTH/YEAR LAST EPISODE
Diabetes mellitus (sugar diabetes)	Y / N	Y / N	_____
Arthritis or pain involving:			
Neck	Y / N	Y / N	_____
Lower Back	Y / N	Y / N	_____
Hips	Y / N	Y / N	_____
Knees	Y / N	Y / N	_____
Ankles	Y / N	Y / N	_____
Require use of cane or other walking aid	Y / N	Y / N	_____
Head, neck or back injury/surgery	Y / N	Y / N	_____
Cancer requiring chemotherapy	Y / N	Y / N	_____

Have you ever had a fall for which there was no clear or identifiable reason (e.g. slippery walk, darkness)? Y / N

If yes:

List the month and year this last occurred? _____

How many times in the past year has this occurred? _____

Approximately how many times has this ever occurred? _____

How would you describe your present state of health? (Circle One)

1.excellent
2.Good
3.Fair
4.Poor

Have you had an ear infection within the last month? Y / N

Do you have any ear problems? Y / N

If yes, please describe: _____

_____

Have you ever had any other injuries or surgeries? Y / N

If yes, please describe:

_____

_____

_____

Are you involved in any regular exercise program? Y / N

If yes,
circle: 0.None 1.walking 2.jogging 3. bicycling

4. swimming 5. weight lifting 6. racket sports

7. (specify)_____

Appendix D

Self-reported Evaluation Checklist / Session Interview

ISCAN/ROOFER STUDY
Self-reported Evaluation Checklist

Name:_____ Subject ID:_____ Date:_____ Phase: ____ Session: _____

Ambient Temperature: _____°F Relative Humidty; _____ % Interviewer: _____

Oral Temperature: _____ °F Blood Pressure: _____/_____

1. What is your occupation? _____

2. How many years have you worked in this occupation? ..... _____ years

Job duties:

_____

_____

3. Have you worked in the last twelve hours? ..... 1. Yes 2. No
   a. If **YES**, how many hours? ..... _____ hours

4. Have you changed shifts in the last week? ..... 1. Yes 2. No
   a. What were the hours of your previous shift? ..... _____ to _____
   b. What are the hours of your current shift? ..... _____ to _____

5. Have you worked on an **elevation** in the last twelve hours?..... 1. Yes 2. No
   (for example: ladder, scaffold, roof, etc.)
   a. If **YES**, how many hours? ..... _____ hours

6. Have you worked on an **incline** in the last twelve hours?..... 1. Yes 2. No
   (for example: dock ramp, roof, etc.)
   a. If **YES**, how many hours? ..... _____ hours

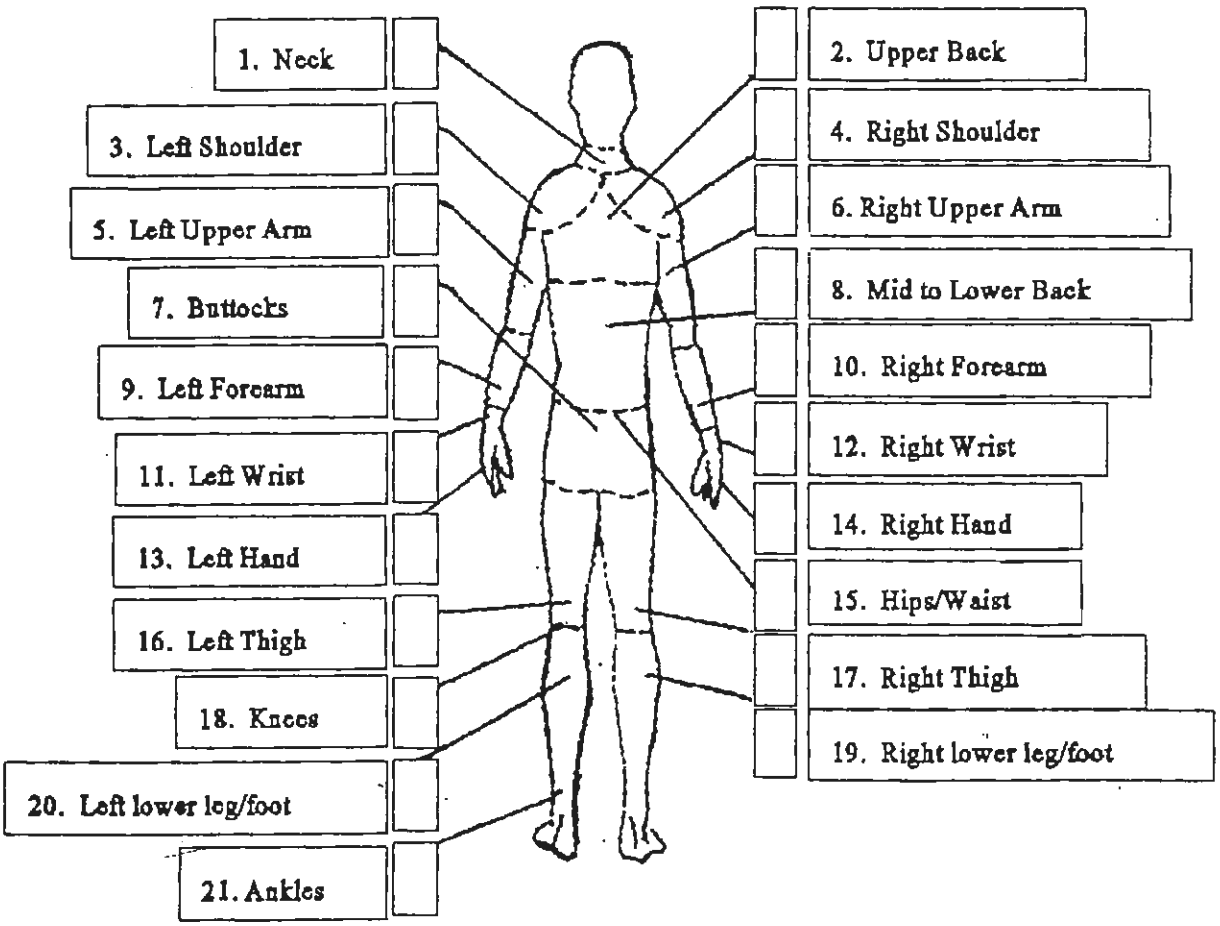
7. Using the rating scale shown below, please rate the **OVERALL** physical effort level you experienced for the last twelve hours? Please circle the most appropriate number on the following scale.

20
19 - Very, very hard
18
17 - Very hard
16
15 - Hard
14
13 - Somewhat hard
12
11 - Fairly light
10
9 - Very light
8
7 - Very, very light
6

8. Have you had any pain or discomfort in the last twelve hours? .... 1. Yes 2. No

IF **NO**, go to next page.
If **YES** , carefully enter a number in **EACH** box using the following scale.
Mark in the appropriate box using the following scale:

0 - Comfortable
1 - Uncomfortable
2 - Very Uncomfortable
3 - Extremely Uncomfortable



In the last twelve hours, on average how much time is spent doing the following activities? Circle a response for the following questions.

	0 Not at all	1 Very little	2 Occasionally	3 Most of the time	4 All the time
9. Working with arms raised above your head/shoulder					
10. Bending at the waist					
11. Turning / twisting of the upper body					
12. Lifting					
13. Carrying heavy objects					
14. Kneeling					
15. Standing					
16. Walking					
17. Climbing					
18. Squatting					
19. Stooping (bending with legs straight)					
20. Pulling (cable, wire, nails, etc.)					

	0 Not at all	1 Very little	2 Occasionally	3 Most of the time	4 All the time
21. Using manual tools					
22. Using power tools					
23. Working outside					
24. Wearing a full-face air purifying respirator					
25. Wearing a half-face air purifying respirator (dust mask)					
26. Wearing a full-face supplied air respirator					
27. Wearing protective hard hat/ helmet					
28. Wearing protective gloves					
29. Wearing protective boots					
30. Wearing other protective clothing					

31. Including lunch, how long is each of your breaks? *If no lunch or breaks enter 00*

*first:*____ minutes *second:*____ minutes *third:*____ minutes *fourth:*____ minutes

32. What was the most physically demanding aspect of your last twelve hours? Please write in the name of the task:

_____

_____

BIOMECHANICS AND ERGONOMICS RESEARCH LABORATORY
SESSION INTRVIEW

NAME:_____SUB ID:_____ DATE:_____ SESSION#:_____

1. Asleep:_____ Woke:_____ #hrs slept: _____

2. Sleep uninterrupted: 1=yes 2=no 3=unknown _____

3. Time ate last:_____ #hrs since last meal _____

4. Caffeine last 12 hours: 1=yes 2=no 3=unknown _____

type: 1=coffee 2=tea 3=soda 4=cocoa 5=combo 6=none _____

amount: enter # ounces _____

5. # cigarettes smoked in last 12 hours: _____

time last cigarette: _____

6. Sick in the last week: _____
hx_____
7. Any recent surgery including dental: _____
hx_____
8. Ear infection since last visit: _____
hx_____
9. Currently taking any meds (last 24 hrs): _____
hx_____
10. Injuries to head neck or back since last visit: _____
hx_____
11. Have you fallen on the job since last visit: _____
hx_____
12. In the last 24 hours, strenuous activity: _____
hx_____
13. Stressful events at home or job in last 24 hrs: _____
hx_____
14. Alcohol consumption in the last 48 hours: _____

type: 1=beer 2=liquor 3=wine 4=none _____

amount consumed: enter # ounces _____

15. Recreational drugs ingested in the last 24 hours: _____

type: 1=marijuana 2=cocaine 3=narcot. 4=other 5=none _____

freq./amount in last 24 hours _____

16. Did you work in the last 12 hours: _____

hours worked _____
type work_____
17. Have you changed shifts in the last week: _____

last shift worked _____

current shift _____

18. BP_____ Pulse:_____

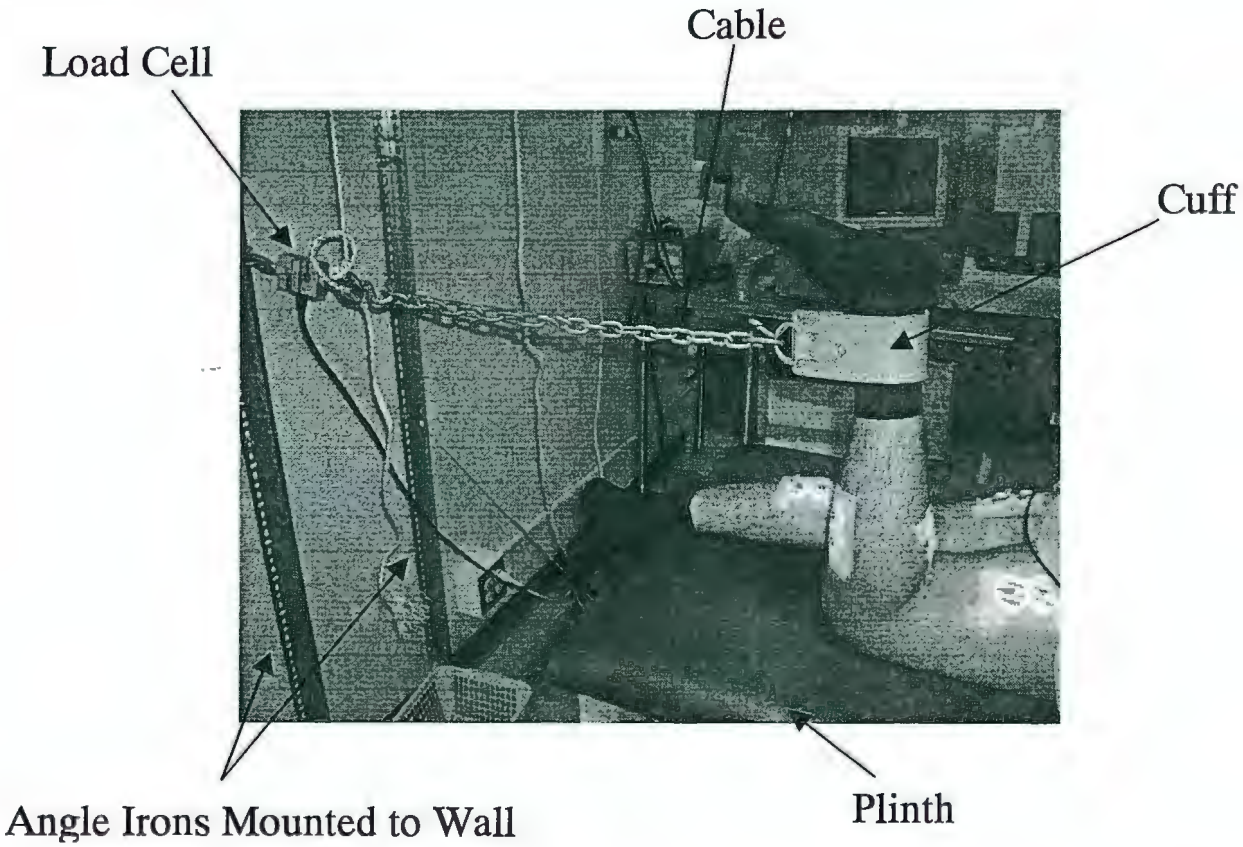
19. Are you pregnant? yes no LMP

Appendix E

Vmax Set-up

Vmax Set-up

(Position shown is for testing the Right Hamstring)



Appendix F

Amplifier Settings for EMAX / Phase 3

Amplifier Settings

The following settings were used for the amplifier for the force platform:

Low Pass Filter (dip switches 1 and 2)

1 and 2 open:	10.5 Hz (used for balance testing)
1 and 2 closed:	1050 Hz (used for EMAX test)

Amplifier Gain (dip switches 3 and 4)

3 and 4 open:	4000 (used for all testing)

Therefore,

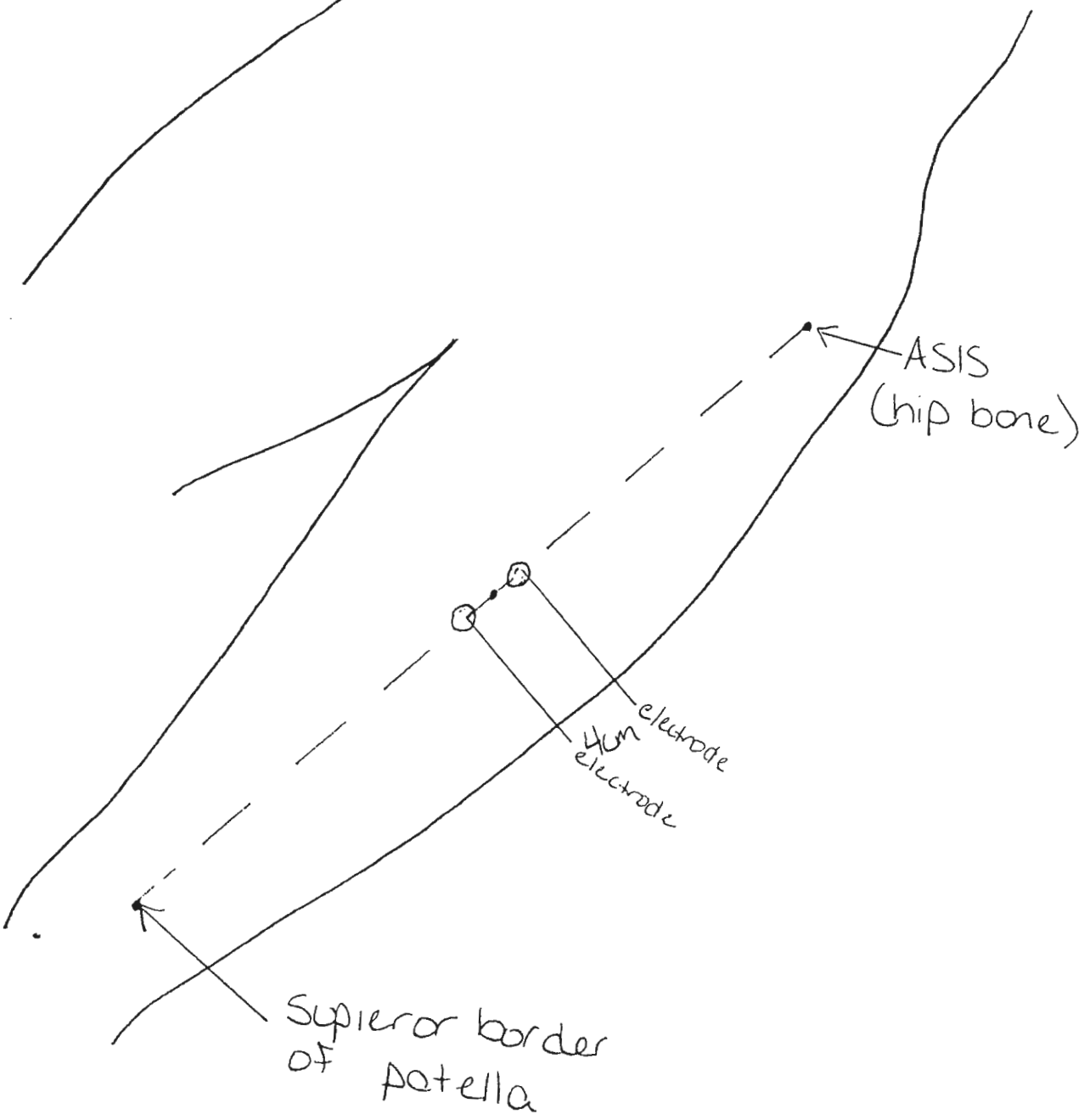
For BALANCE
All open

For EMAX
1,2 closed
3,4 open

Appendix G

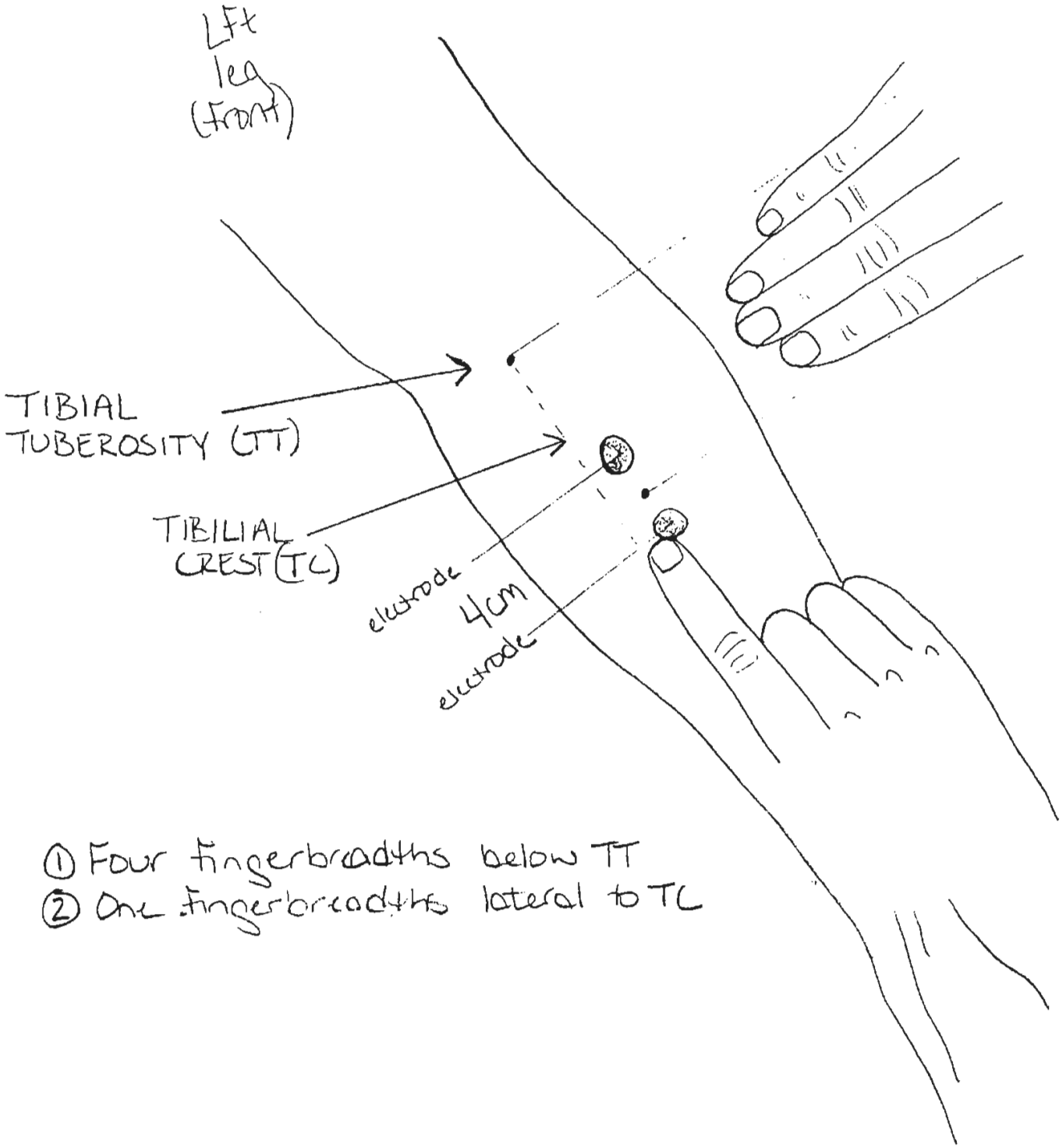
Placement of EMG Electrodes

QUADS



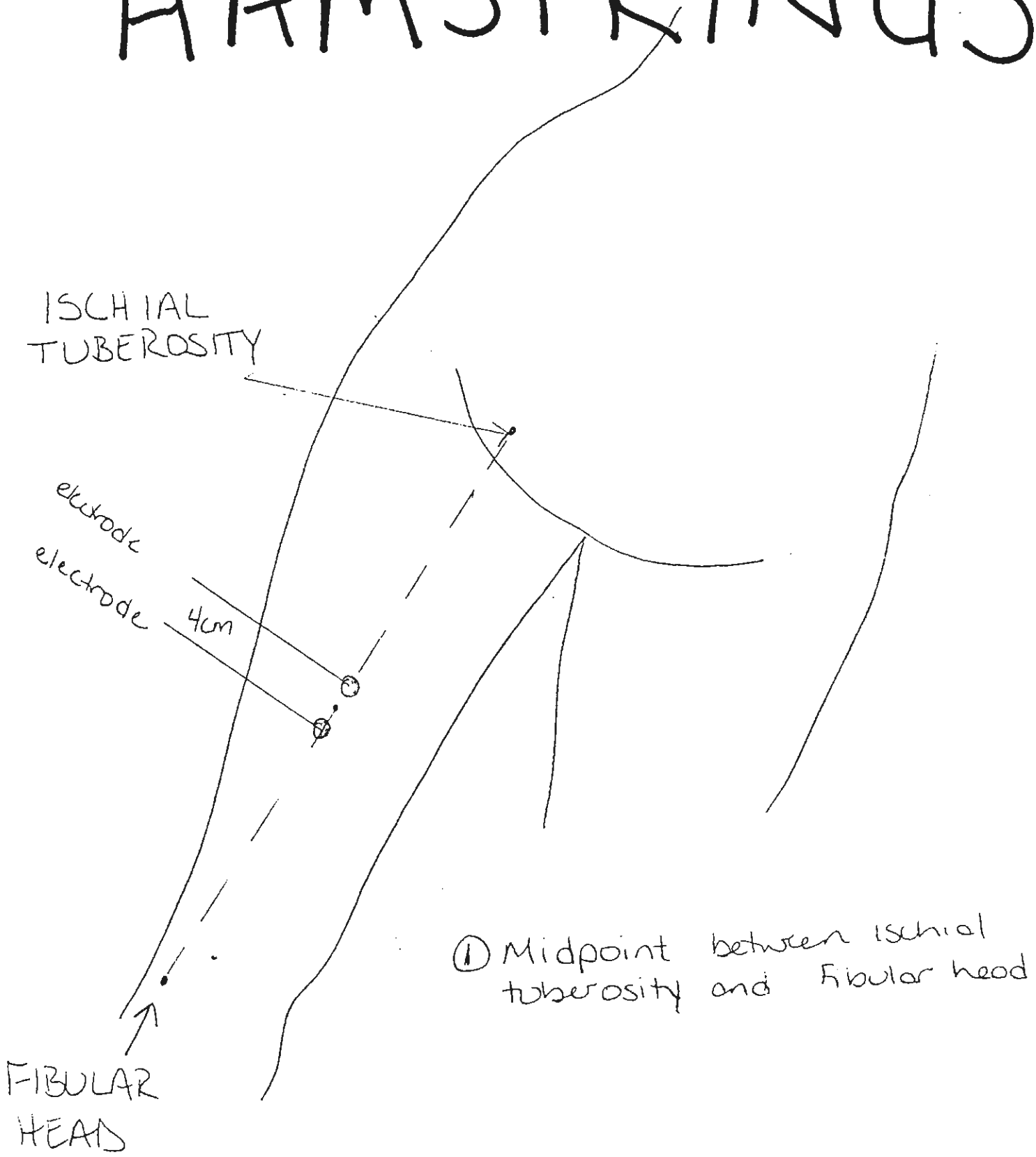
① Midpoint between Asis and Patella.

TIBIALIS ANTERIOR



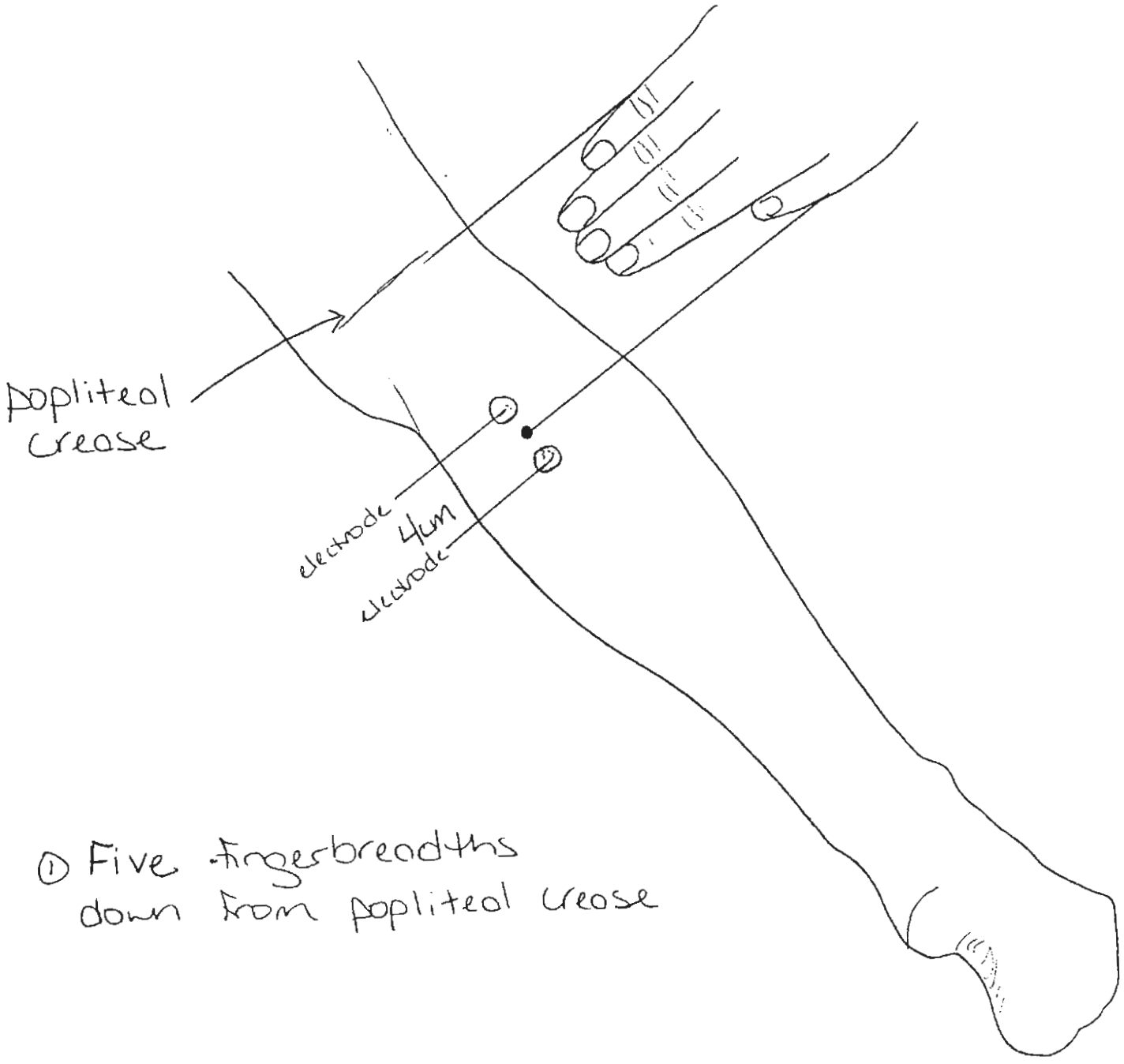
① Four fingerbreadths below TT
② One fingerbreadths lateral to TC

HAMSTRINGS



① Midpoint between ischial tuberosity and fibular head

GASTROCNEMIUS

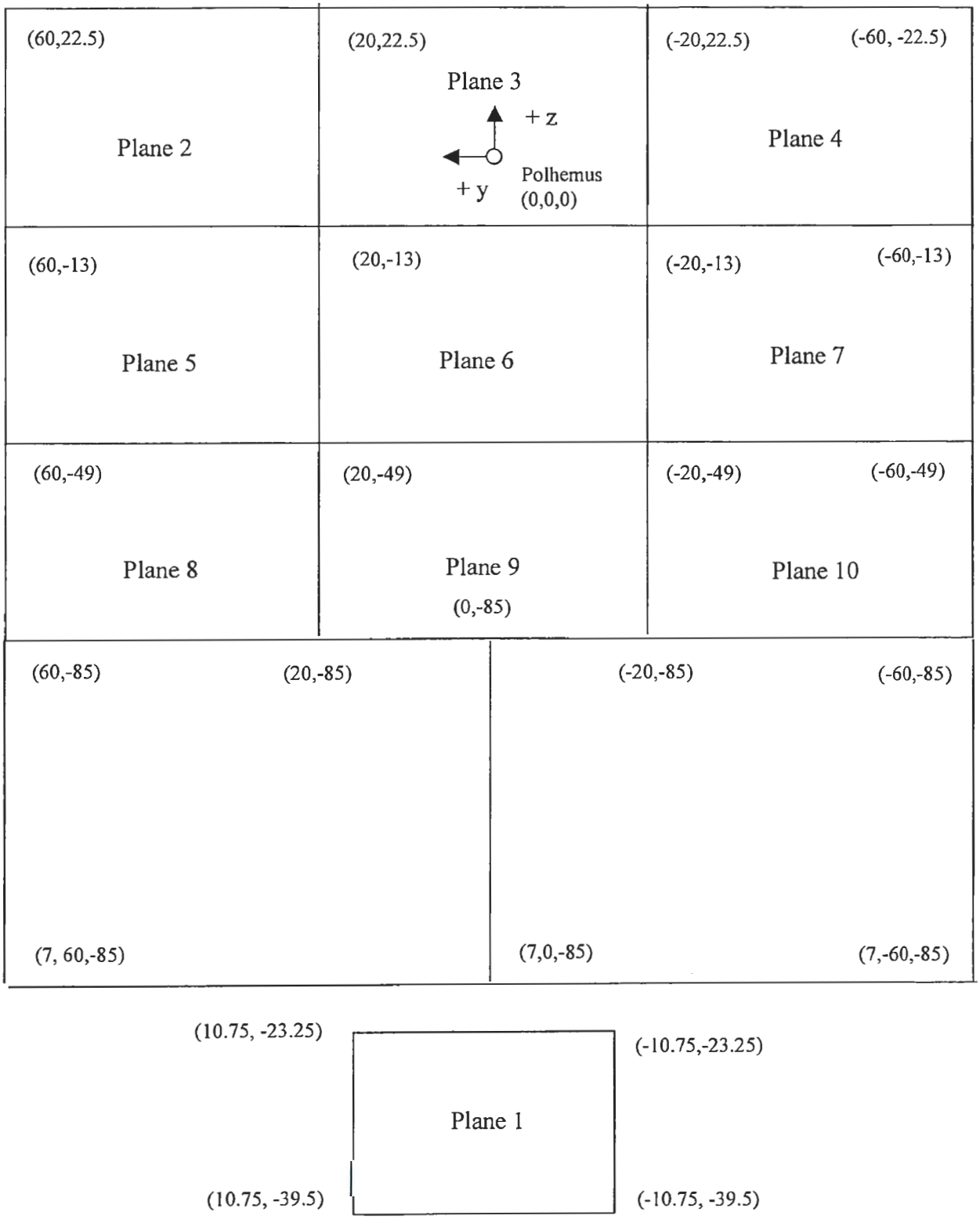


① Five fingerbreadths down from popliteal crease

Appendix H

Plane Definitions for ISCAN

Appendix H. The Polhemus coordinate system. X is the distance from the Polhemus source to the front wall and was 100.75 for all planes except for plane 1, when it was 100. The coordinates given below are (y,z)except for the lower coordinates for planes 11 and 12, then it is (x,y,z). Plane 1 is "inside" plane 6 and is shown at the bottom.



Appendix I

Operator Instructions for ISCAN

ISCAN " QUICK" INSTRUCTIONS

- Press "i" and *<return>* to **start ISCAN** program.
- To **define planes, hit "1"** from main menu.
  - hit "1" to read planar coordinates
  - Enter name of file with desired planes previously defined
  - Enter "c" to continue
  - Check figure and hit any key to continue
  - Hit 4 to return to main menu
- To **run headhunter system, hit "2".**
- Ensure that crosshairs are stable in eye monitor, if not adjust.
- To **boresight:**
  - Have subject center his/her head to the middle of first plane.
  - Press "G", wait ~5 seconds.
- To **calibrate** (subject should be looking at monitor with a video playing)**:**

  Point or Regard (POR)
  - The mode should be "POR", if not hit "M" until you see "POR"
  - Press "R"
  - Press "C" to begin calibration.
  - Ask subject to look at appropriate marker.
  - Make sure subject is not blinking and you can see both crosshairs clearly in the eye monitor.
  - Adjust circle in scene monitor with cursor to cover appropriate marker.
  - Press "E" to enter that calibration.
  - Continue until you finish all markers.
  - Press "R"
  - Press "N" to run the system.
  - Ask subject to look at the markers again to ensure proper calibration . If it is not, repeat by pressing "R" to reset then "C" to calibrate again.

  Eye Angle
  - Set the mode to "Eye Angle"
  - Press "R"
  - Press "C" to begin calibration
  - Ask subject to look at appropriate marker.
  - Make sure subject is not blinking and you can see both crosshairs clearly in the eye monitor.
  - Press "E" to enter that calibration.
  - Continue until you finish all markers.
  - Press "R"
  - Press "N" to run the system.
  - Play calibration video to ensure proper calibration. If it is not, repeat by pressing "R" to reset then "C" to calibrate again.

- To **record data:**
  - Record data point starting at.
  - Press "B" to begin data collection.
  - Press "Q" to quit.
  - Record ending data point. (It will be one less than the number shown in Pts. Rec.)
- To **save data:**
  - Press "esc" to return to main menu.
  - Save according to what information/file type you want.
- To **record more data,** press "2" to return to system and begin the calibration again. **note** redefine planes if the desired planes have changed.

Appendix J

Operator Instructions for OPTEC and Datasheet Form

Industrial Vision Tester
Testing Procedures

Adjust the chair and OPTEC device such that the subject is as comfortable as possible. Explain to the subject the following:

- Pressing their forehead on the device activates the device.
- If at anytime they feel uncomfortable, they can sit back and relax.
- They should not guess at seeing things!!

Test 1 – Demonstration Slide	
FAR RIGHT ON LEFT ON	What color is the dot at the end of the road? *dark brown indicates both ,* *red indicates right eye , green indicates left eye*

Test 2 – Far Acuity – Both Eyes	
FAR RIGHT ON LEFT ON	Look at the first target, is the circle at the TOP complete or broken like the other circles? *Complete*
	Continue asking where the complete circles are. If the subject misses two consecutively, mark the last correct response on the data sheet.

Test 3 – Far Acuity – Right Eye	
FAR RIGHT ON LEFT ON	Look at the first target, is the circle at the TOP complete or broken like the other circles? *Complete*
	Continue asking where the complete circles are. If the subject misses two consecutively, mark the last correct response on the data sheet. If subject has problems seeing the targets, record on datasheet and have subject close the left eye.

Test 4 – Far Acuity – Left Eye	
FAR RIGHT ON LEFT ON	Look at the first target, is the circle at the LEFT complete or broken like the other circles? *Complete*
	Continue asking where the complete circles are. If the subject misses two consecutively, mark the last correct response on the data sheet. If subject has problems seeing the targets, record on datasheet and have subject close the right eye.

Test 5 – Stereo Depth	
FAR RIGHT ON LEFT ON	Study target #1, do you see that the bottom circle is floating or 3-D? Identify the same type of circle for each target.
	If the subject has problems seeing the floating circle, have them sit back and relax their eyes and try again.

Test 6 – Color	
FAR RIGHT ON LEFT ON	Do you see a number in A? B? etc…

Test 7 – Far - Vertical Phoria	
FAR RIGHT ON LEFT OFF	Do you see a series of musical notes? How many do you see? *7.* I am going to draw a red, horizontal line. Tell me which note the line passes through. Please respond quickly. TURN ON LEFT.

Test 8 – Far - Lateral Phoria	
FAR RIGHT ON LEFT OFF	Do you see a series of musical notes? How many do you see? *15.* I am going to draw white arrow. Tell me which note the arrow points to. Please respond quickly. TURN ON LEFT.

Test 9 – Near Acuity – Both Eyes	
NEAR RIGHT ON LEFT ON	Look at the first target, is the circle at the RIGHT complete or broken like the other circles? *Complete*
	Continue asking where the complete circles are. If the subject misses two consecutively, mark the last correct response on the data sheet.

Test 10 – Near Acuity – Right Eye	
NEAR RIGHT ON LEFT ON	Look at the first target, is the circle at the TOP complete or broken like the other circles? *Complete*
	Continue asking where the complete circles are. If the subject misses two consecutively, mark the last correct response on the data sheet. If subject has problems seeing the targets, record on datasheet and have subject close the left eye.

Test 11 – Near Acuity – Left Eye	
NEAR RIGHT ON LEFT ON	Look at the first target, is the circle at the BOTTOM complete or broken like the other circles? *Complete*
	Continue asking where the complete circles are. If the subject misses two consecutively, mark the last correct response on the data sheet. If subject has problems seeing the targets, record on datasheet and have subject close the right eye.

Test 12 – Near - Lateral Phoria	
FAR RIGHT ON LEFT OFF	Do you see a series of musical notes? How many do you see? *15.* I am going to draw white arrow. Tell me which note the arrow points to. Please respond quickly. TURN ON LEFT.

STEREO OPTICAL INDUSTRIAL VISION TESTER RECORD FORM

Far Point (20 Ft.) Tests

	TEST DISTANCE	INTERMEDIATE DISTANCE TEST													
	INCHES	20		22		26		31		40					
	CM	50		57		66		80		100					
	Demonstration														
	Slide														
	Alternate														
1	Target	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2	Both Eyes	↑	→	→	←	↑	↓	←	→	←	↓	→	↓	↑	→
3	Right	↑	←	↑	↑	↓	↓	←	↓	→	↑	→	←	↓	→
4	Left	←	→	←	↓	→	↑	↑	↓	→	↑	↓	→	↑	←
	Snellen Equivalents	20/200	20/100	20/70	20/50	20/40	20/35	20/30	20/25	20/22	20/20	20/18	20/17	20/15	20/13
5	Stereo Depth	1 ↓		2 ←		3 ↓		4 ↑		5 ↑		6 ←		7 →	
		8 ←		9 →											
6	Color	A 12			B 5			C 26			D 6			E 16	
		F 0													
7	Vertical	1			2			3			4			5	
		6			7										
8	Lateral	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

14" ☐ other

9	Target	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
9	Both Eyes	→	←	↑	→	↓	→	↑	←	↑	←	↓	→	↓	←	
10	Right	↑	↓	↑	↓	→	↑	→	←	↓	←	→	→	←	↑	
11	Left	↓	←	↓	→	↑	←	↑	↓	→	→	←	→	↑	→	
12	Lateral	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Name _____

Employee Number _____

Occupation _____

Department _____

Date _____ Age _____

Contact Lenses: Yes ___ No ___

Bifocals ___ Trifocals ___

Specials _____

Last Exam By Doctor _____

Change Rx Yes ___ No ___

Tester _____

Comments _____

Referred: Yes ___ No ___

Employee Signature

Perimeter Score

Right Peripheral

85° 70° 55° Nasal 35°

Left Peripheral

85° 70° 55° Nasal 35°

OPTEC Data Entry

TEST	*description*	*DATA ENTRY*	*ANALYSIS*
1		none	none
BF2	both eyes far	1 through 14	1 2 3 4 5 6 7 8 9 10 11 12 13 14
RF3	right eye far	1 through 14	20/200 20/100 20/70 20/50 20/40 20/35 20/30 20/25 20/22 20/20 20/18 20/17 20/15 20/13
LF4	left eye far	1 through 14	
SD5	stereo depth	1 through 9	1 2 3 4 5 6 7 8 9 NOTE:
			15 30 50 60 70 75 82 90 95 85 is average
C6	color	1 through 8	Fail Mild Deficiency Normal
		(# digits correct)	< 5 >5 8
VERF7	vertical far	1 through 7	2.5 to 5.5 is normal
LATF8	lateral far	1 through 15	3.5 to 13.5 is normal
BN9	both eyes near	1 through 14	1 2 3 4 5 6 7 8 9 10 11 12 13 14
RN10	right eye near	1 through 14	20/200 20/100 20/70 20/50 20/40 20/35 20/30 20/25 20/22 20/20 20/18 20/17 20/15 20/13
LN11	left eye near	1 through 14	
LATN12	lateral near	1 through 15	3.5 to 13.5 is normal
RP85	peripheral	Y/N	
RP70	peripheral	Y/N	
RP55	peripheral	Y/N	
RP35	peripheral	Y/N	
LP85	peripheral	Y/N	
LP70	peripheral	Y/N	
LP55	peripheral	Y/N	
LP35	peripheral	Y/N	

Appendix K

Operator Instructions for MK-70

Instructions for Peripheral Visions Screening

Supplies needed: 2 sterile eye pads
2 perimeter graphs
Eye patch

When subject arrives:

- Load the chart fixation plate with the graph.
- Explain in detail what will happen during test and how he/she will respond using the buzzer when the stimulus is spotted.
- Clean the head rest, chin rest and eye patch with sterile alcohol pads while subjects observes. Place fresh sheet of paper in the head rest.
- Have subject place one of the sterile eye pads in the eye patch and occlude the left eye. The right eye will be tested first. When ready to test the left eye replace eye pad with fresh one.
- Fix the subjects head on the headrest with the headband. Make sure the subject is sitting in a comfortable position.
- Give subject two to three minutes adaptation to the illuminated perimeter and then a practice stimulus.

Great attention is required of the subject, and anything that might divert him from active cooperation should be avoided. The examination of one eye should not exceed more than 15 minutes.

Explain the procedure to the subject in simple words that are easy to understand e.g. "Please press the buzzer the moment you see a white spot appear in the periphery". The instruction to maintain good fixation is repeated at the beginning and throughout the test as needed.

The subject should be sitting comfortable in front of the instrument and the eye not being tested completely occluded. When the target first appears in his visual field the subject is inclined to look away form the fixation point and forgets to sound the buzzer. Observe the subjects eye during the examination through the telescope and immediately recall the subject's attention to the fixation point.

The examiner positions him/herself in front to the perimeter with the telescope at eye level. One eye constantly supervises the fixation of the subject's eye; the other watches the index of the pantograph as it is guided over the chart.

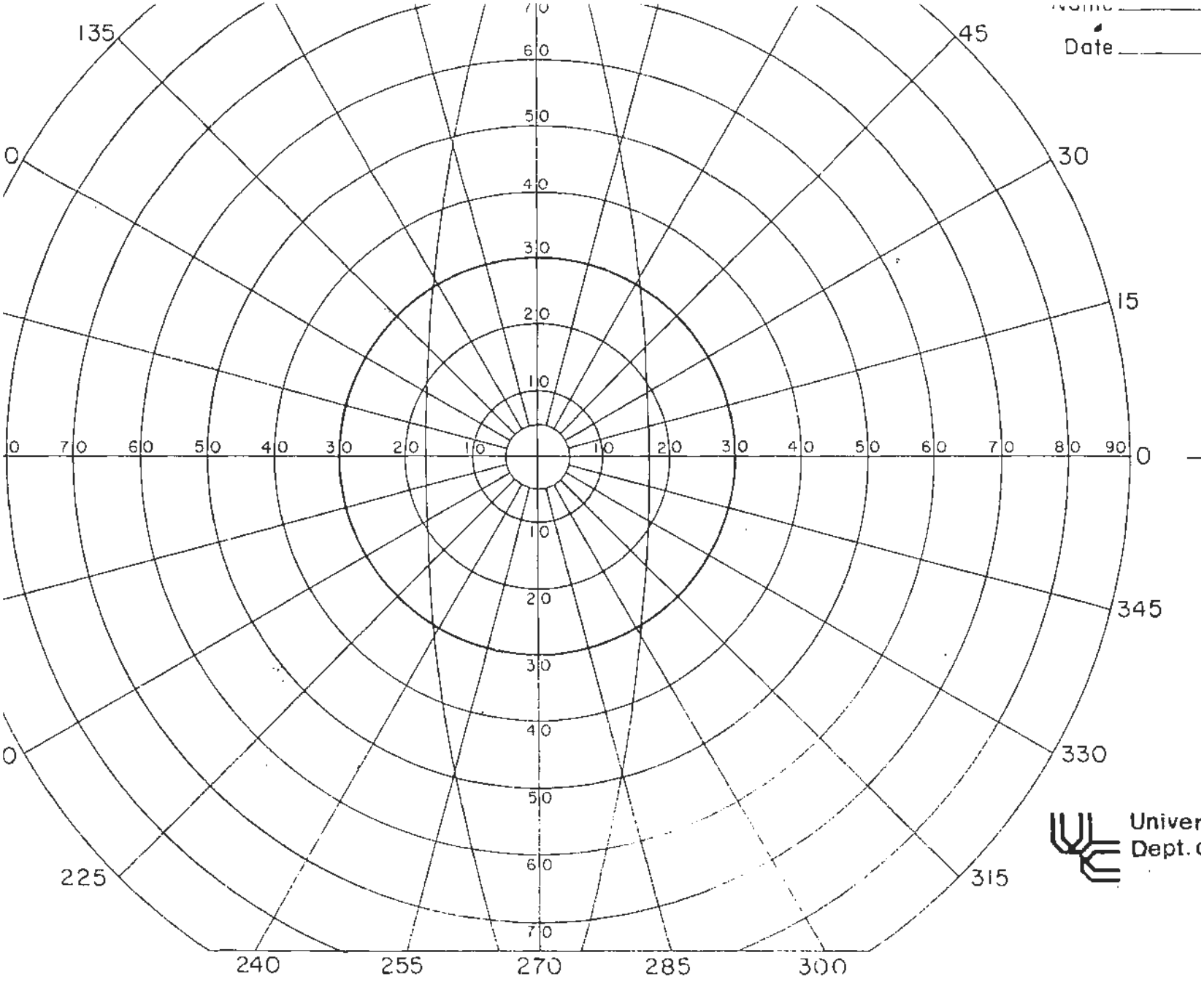
Center the subject's eye exactly by turning he two knurled knobs (I) and (J). If adjustments are necessary during the testing, notify the subject that the may feel a slight movement of their chin either up, down, right or left as needed.

Using a demonstration setting of I4E move the target at a constant speed of about 1° to 2° a second from the invisible to the visible area of the periphery towards the center, marking the threshold when the subject sounds the buzzer. If the subject has trouble seeing the target, increase the intensity and or size by one setting at a time until the necessary target size is obtained. Note settings used during the test on the graphs.

When the projector has to be moved from one half of the field to the other, it can only be done by lightly guiding the index of the handle approximately along the arrowed line at the bottom of the recording chart. Line (a) indicates the limit of he target's movement in the left half of the sphere and the line (b) its limit in the right half of the visual field. The movement from one half of the field to the other should be smooth and swift.

Note that if a blind spot is noticed at 15° to 20° this is normal for most. Examine the blind spot with the target whose isopter just includes the area of the blind spot (normally I/1 or I/2) or with an intensity one grade higher if the isopter passes at 20°.
Continue testing until all angles and sectors have been tested and a point is plotted for each.

At the conclusion of each eye examined, mark the graph with subject ID, which eye tested (OD - right, OS - left), settings used, date of test, and any comments or unusual findings. Join the points plotted on the chart to create an outline of the visual field.


Name
Date
135
45
0
30
15
0
345
0
330
225
315
240
255
270
285
300
10
20
30
40
50
60
70
80
90
OS
OD.
Univer
Dept.

Appendix L

Borg Scale

Category Scale for Rating of Perceived Exertion, 1980: Large Muscle-Group Activity

Following each of the fatiguing tasks you will be asked to rate your perceived sense of exertion. Another way of saying this is how hard did your muscles work. In this rating scale we are asking you to tell us how hard or how much exertion you experienced for the body overall. Rate your whole body as one unit. Example: If you feel that your are ready to collapse you may rate your exertion 10. If you feel that you worked strong/heavy/hard you may use the rating 5. Remember there are no right or wrong answers. This is a subjective rating of your experience for a particular trial/task.

	Maximal
10	Very, very strong (almost max)
9	
8	
7	Very strong
6	
5	Strong (heavy)
4	Somewhat strong
3	Moderate
2	Weak (light)
1	Very weak
0.5	Very, very weak (just noticeable)
0	Nothing at all

Appendix M

Modified Bishop-Corlett Scale

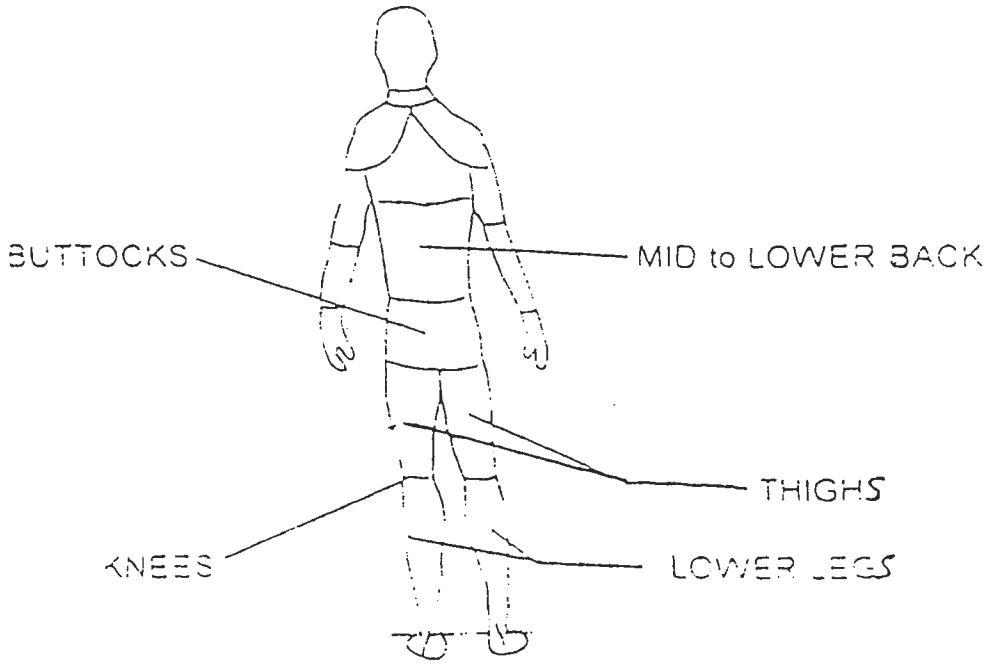
Modified Bishop-Corlett Discomfort Scale

During some of the tests you will perform a task that is designed to fatigue or work the muscles in the legs. Following the fatiguing task you will be asked to rate how much discomfort you experienced in certain body parts. Please note the scale is 0 to 3, with 0 being no discomfort and 3 being extremely uncomfortable. Example: If your lower back is slightly uncomfortable you may answer 1, if your thighs are very uncomfortable you may answer 2, etc.

Each body segment that is rated may have a different answer/rating. For rating purposes we will consider the knees, thighs, lower legs as each being a unit. In other words, unless you experience more discomfort in the right vs left rate them as one. Both knees as a unit would get a rating, both legs as a unit would get a rating and both thighs as a unit would get a rating. Please tell us if there is a significant difference in right vs left of either unit.

Remember there are no right or wrong answers. This is a subjective rating of your experience for a particular trial/task

Discomfort Scale
0 - No Discomfort
1 - Uncomfortable
2 - Very Uncomfortable
3 - Extremely Uncomfortable



Appendix N

PSOF Scale

RATING OF PERCEIVED SENSE OF FALL DURING A POSTURAL STABILITY TEST

Sway is defined as movement from side to side or back and forth. Even while standing still everyone experiences body sway. This can be felt by the individual as a gentle pendulum like movement in seemingly random directions of the body. In reality, the body's sway is caused by contraction and relaxation of muscle groups. This causes the body to sway or pivot at joints such as the ankles, knees, waist, and neck. After each Postural Stability Test you will be asked to estimate your total body sway. Indicate the number that corresponds best with what you felt. For instance, if you felt your body sway somewhere between a little and some, you may use the rating -0.5-.

Remember there are no right or wrong answers. This is a subjective rating of your experience for a particular trial/task

1. How much did you feel your body sway (i.e., rotate, pivot)?

a little		some		a lot
-0-	-0.5	-1-	-1.5-	-2-

2. Did you have any difficulty in maintaining balance (how much did you or your muscles compensate for your movement)?

none		a little		a lot
-0-	-0.5-	-1-	-1.5-	-2-

3. Did you feel at any time that you would fall?

none		a little		a lot
-0-	-0.5-	-1-	-1.5-	-2-

4. What would you say was the overall difficulty of this task?

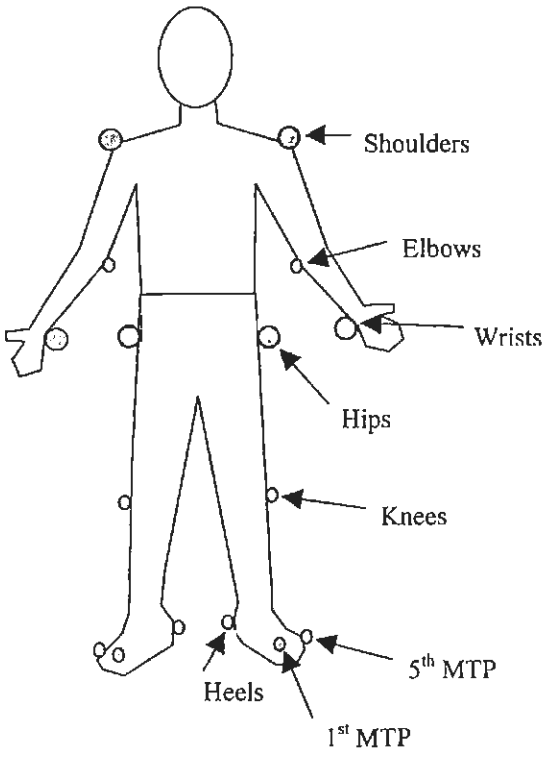
very easy	easy	moderate	somewhat hard	hard
-0-	-0.5-	-1-	-1.5-	-2-

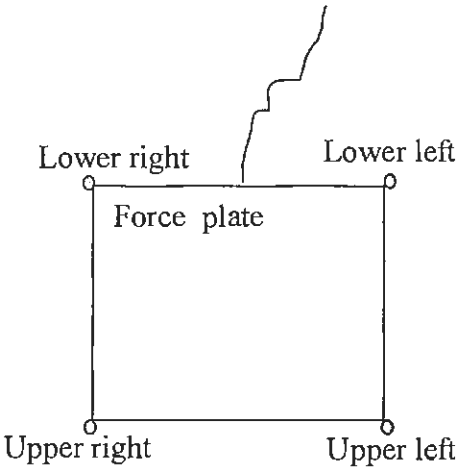
Appendix O

Marker System

Marker System

(16 on subject, 4 on plate)





Appendix P

VMAX Testing Positions

MAXIMUM VOLUNTARY CONTRACTION (use DISC A)

See accompanying figures for subject positioning for quads, hams, tib ant. gastrocs

Once subject is in position for max. contraction, subject is instructed to maximally contract over 1 second (start the EMG collection one second before contraction begins) and maintain exertion for 4 seconds.

Select one probe to be connected to channel 1- quickest set-up pattern is:

R QUADS- Connect ground and R quads

L GASTROCS- maintain ground and change the muscle probe buttons to L gastrocs.

R TIBIALIS ANTERIOR- as above for R Tib. Ant.

R HAMSTRINGS- Etc.

L QUADS

R GASTROCS

L TIBIALIS ANTERIOR

L HAMSTRINGS

Once the subject is in position, the load cell is connected and the appropriate electrodes are buttoned on, the standard instructions are :

Push into this direction (show them the movement) as hard as you can after I say ready, steady, go. Continue to hold the contraction until I say stop.

Switch remote on- WAIT FOR ONE SECOND

Say- "Ready, Steady, Go" for contraction while simultaneously switching on the load cell

Each exertion should be repeated until it is apparent that a max. force output is measured on the load cell- viewed on the oscillator as a constant maximum level (average load cell value for the 5 secs is maximum). Repeat three times. Do not repeat maximum voluntary contraction trials more than 3 times (i.e. do not want any fatigue)

Details of posture strength testing

1. Equipment and materials needed

- Plinth
- Load Cell (Jackson Evaluation system; Model 32528; serial 280256; voltage 120; Freq 60; Watts 5)
- Strong cables of adjustable length
- Links to be attached to the end of the cables
- Vertical angle iron for load cell (that allows height adjustability)
- Easily removable hooks
- Straps to stabilize subject during plantarflexion
- Cuff for subject-cable attachment

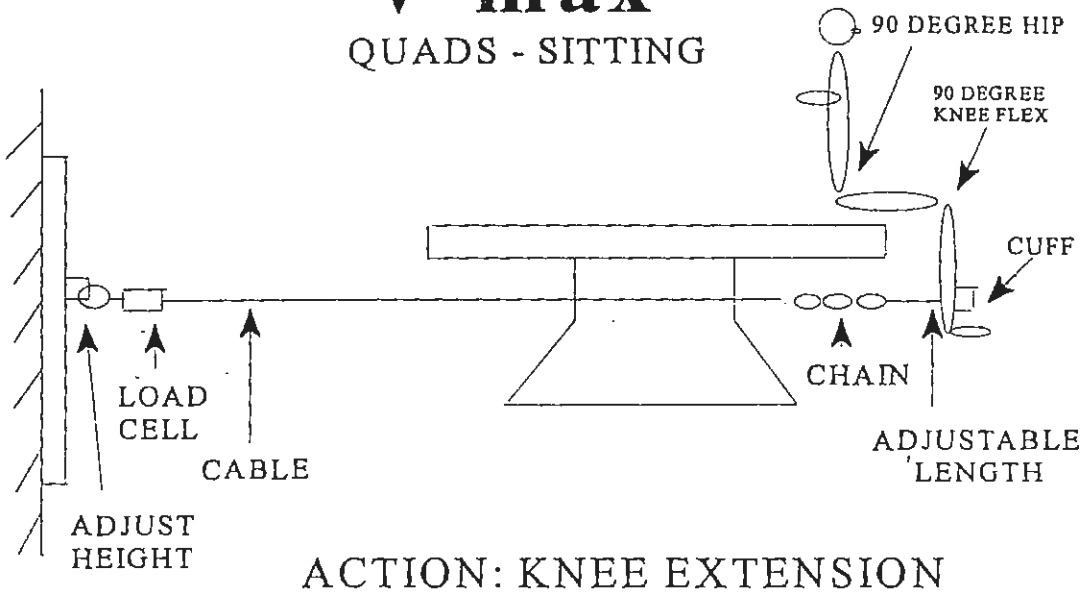
2. Arrangement of plinth and accessories

- The plinth was set at a standard distance from a steady wall
- Two vertically standing angle irons were bolted to the wall at a set distance from each other. The angle irons were placed so that they were symmetrically equidistant when aligned from the edges of the plinth (allowing both the right and left muscles to be tested).
- Two cables of with metal links at ends (for adjustability) were prepared.
- The load cell was connected directly to the vertical angle iron by a removable hook. The cable was connected to the load cell by a removable hook.
- The load cell was connected to an oscillascope which indicated the degree of contraction (Tektronix; NIOSH Property 13133; Model 5113; SN B114467; General Electric 115945)
- A cuff was placed at the end of the cable at a distance which allowed the required positions to be attained.

For each muscle contraction, the cable was aligned (vertically and horizontally)so that it was parallel to its line of pull. Straps were connected to the top end of the plinth so that the subject could be stabilized by two diagonal straps over the thorax and one transverse strap across the waist.

V-max

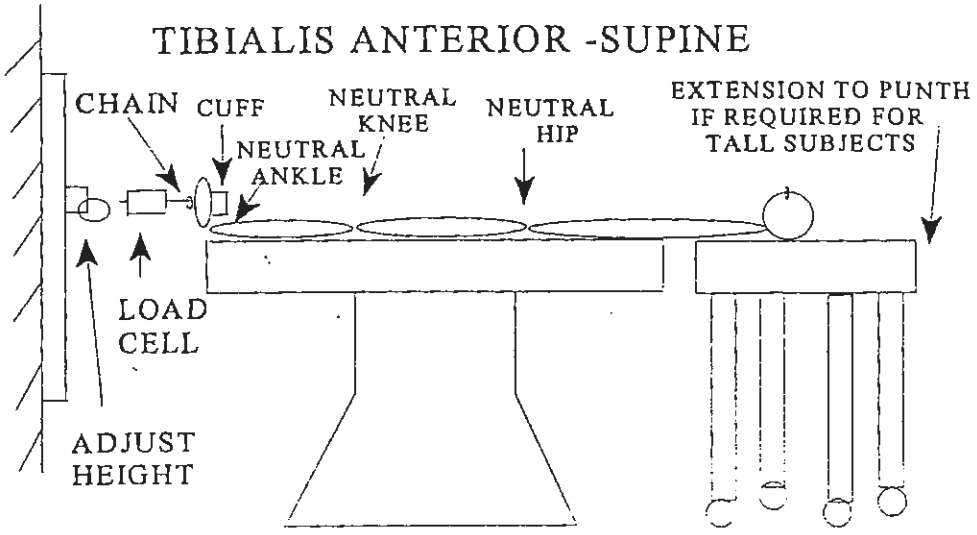
QUADS - SITTING



ACTION: KNEE EXTENSION

V-max

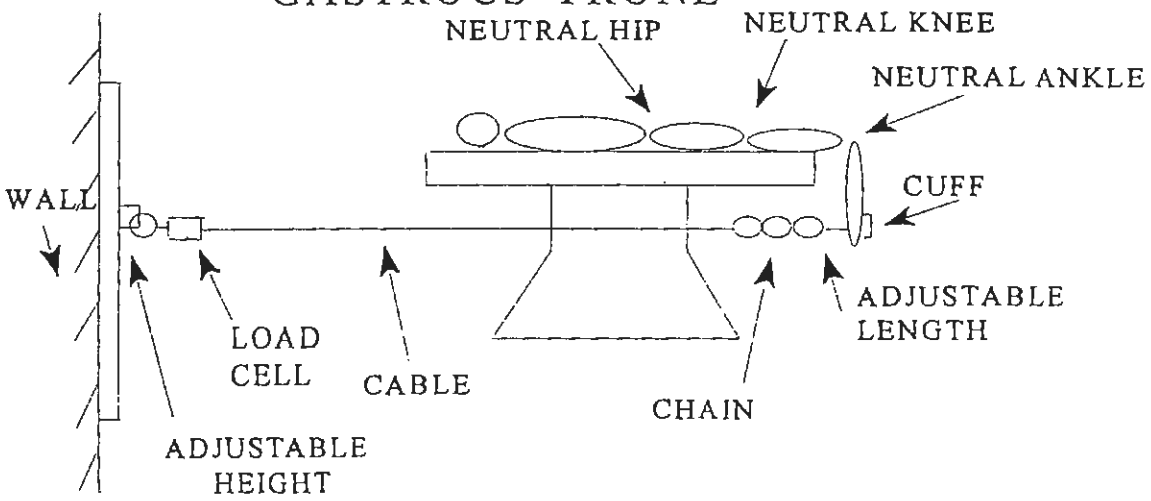
TIBIALIS ANTERIOR -SUPINE



ACTION: DORSIFLEXION

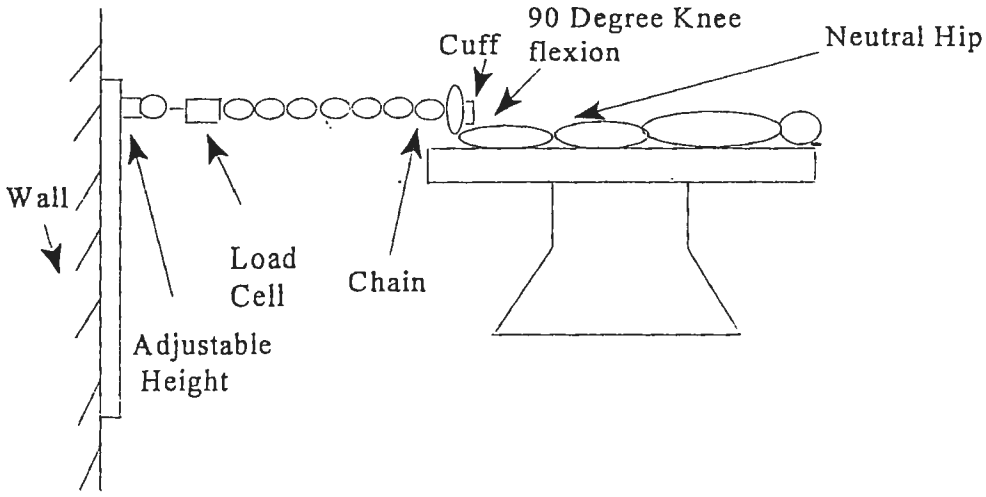
V-MAX

GASTROCS -PRONE



ACTION: PLANTAR FLEXION

V-MAX
HAMSTRING-PRONE



ACTION: KNEE FLEXION

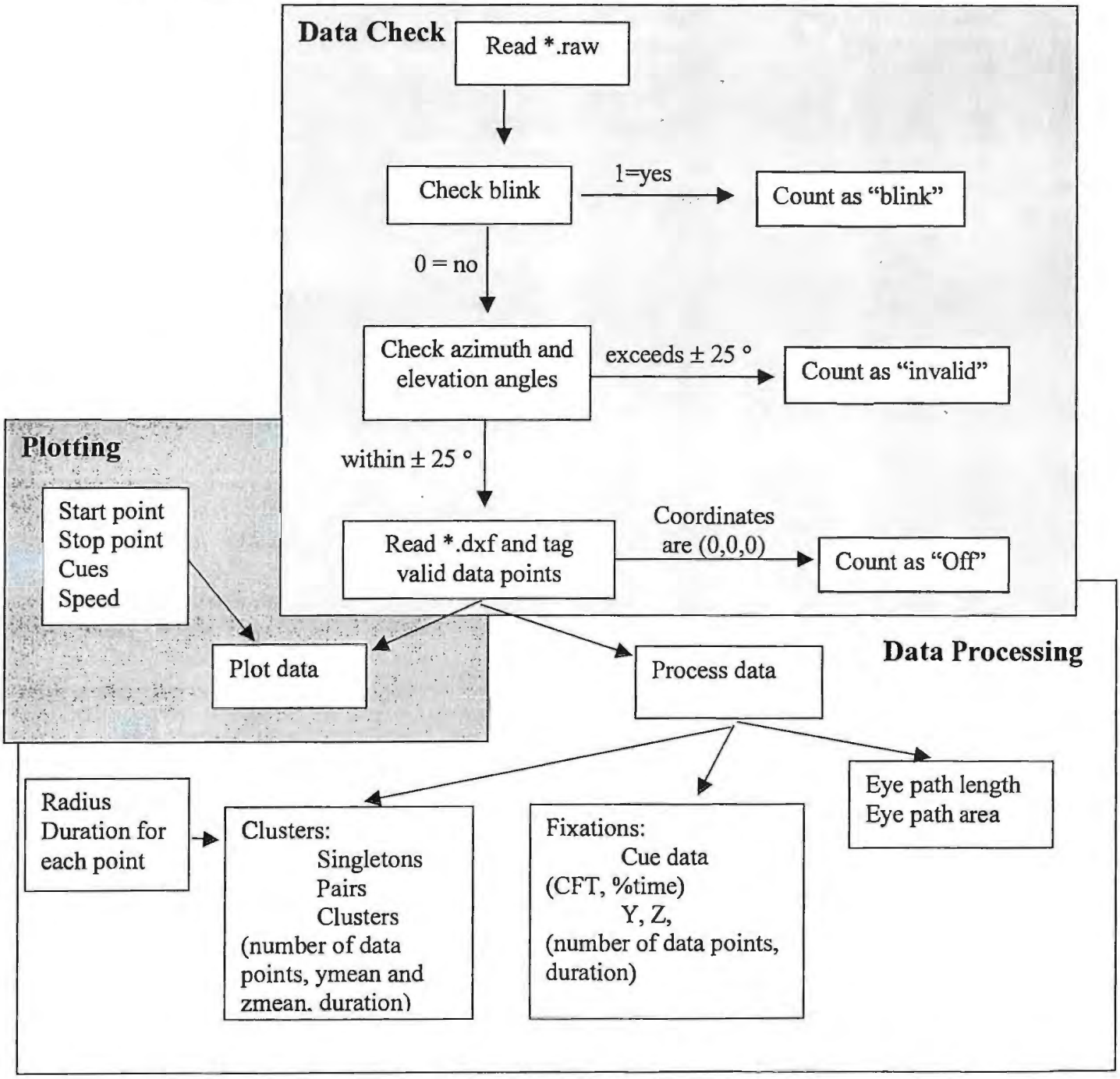
Appendix Q

ISCAN Analysis Program Description

IScan Analysis

The purpose of the IScan Analysis program is to plot and analyze ISCAN eye movement data in 12 pieces of planes. Before plotting and analyzing the data, the program tests the data to insure it is valid eye movement data.

The program reads data collected with ISCAN eye tracking system (ver.los1-11d). Specifically the raw eye movement data file (*.raw) and the AutoCad file (*.dxf) are used in the program. The following flow chart describes the general algorithm.



The main frame for this program is shown as following:

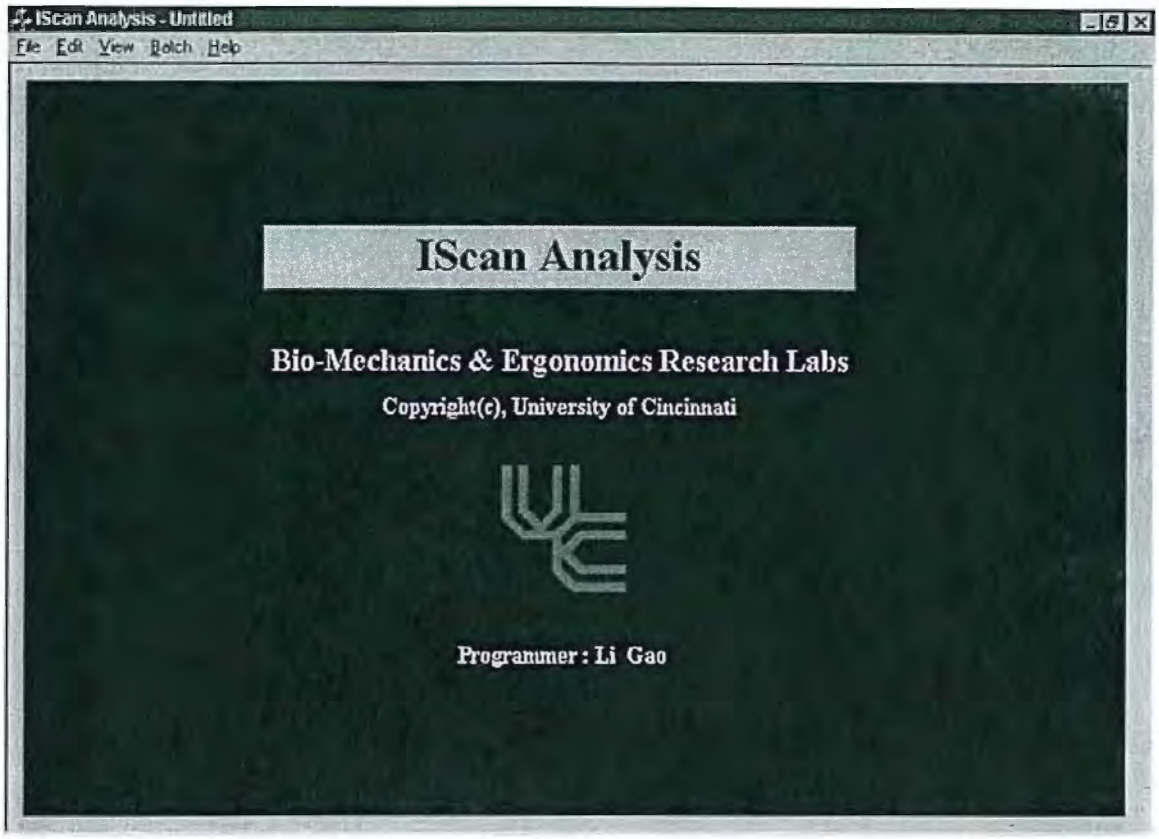


Figure 2. Main Frame for Iscan

Data Check

In the ISCAN data, there are some data points that are not valid eye movements. These invalid data points occur during a blink or when either the pupil cross hair or corneal reflection crosshair is off the correct position. The pupil cross hair will sometimes be deflected onto the eyelashes or lost if the subject is looking down and the upper eyelid covers the pupil. The corneal reflection cross hair will sometimes be deflected to another reflection in the eye such as a tear, the eyelid, or reflections from the infrared lights used to videotape the kinematic data.

Four types of data can be obtained from the data. These include: **(1) blink data:** these are still valid data but indicates that the subject was not receiving any visual input since the eyes were closed; **(2) invalid data:** the eyes are open but either one or both of the crosshairs are off the proper position; **(3) valid data:** the eye was open and both the pupil and corneal reflection crosshairs were in the proper position and **(4) off data:** these are valid eye movement data, but the subject was looking off of the defined planes. To categorize these types of data, criteria were developed using the information from the raw data files. Function declaration in program is int IScanObject::GetVIBZ(int *valid, int *inval, int *blink, int *zeros).

A blink data point can be determined directly form the raw file. Also, after looking at typical data, it was found that data points immediately following a blink might not be valid due to the cross hairs returning to the correct position. These data points are tested as the rest of the data points, but are labeled a blink even though they are indicated as a blink in the raw file. The criteria for al the data points is the angle of elevation and azimuth. The ISCAN software and hardware sets the tracking eye movement, limits eye angle to approximately ± 25°. Therefore, if an angle exceeds these limits, in either azimuth or elevation, the data point must be invalid. From the valid data points, it was found that some had coordinates of (0,0,0). This indicates a valid eye movement, but the subject was looking away from the predefined planes. The following summarizes how the data is categorized:

"Blink" for a blink data point or a data point immediately after at least 4 blink data points that exceeded the angle limits but was at least 10 data points after.

"Valid" for a data point that was not a blink and did not exceed ± 25° in either the azimuth or elevation eye angle.

"Off" for a valid data point with (0,0,0) coordinates in the dxf file.

"Invalid" for a data point was not a blink and exceeded ± 25° in either the azimuth or elevation eye angle.

Input files Manipulation

There are two input files, and they have to be same name except the extension name. One is raw eye movement data file (*.raw) and another one is AutoCad file (*.dxf). Each input file is read in a separate class as following:

RAWData class:

Main function declaration:
int ReadRAWFile(CString fname);

Return Values: 0 - Success; 1 - File not Found; 2 - Invalid Raw File Format

Categorize the data into three types - total 100%
B - for Blink, if blink=1 or (blink =0 but (abs(eyeaz)>25 or abs(eyeel)>25) and afterblinkcount <10);
1 - for Invalid, if blink=0 and (abs(eyeaz)>25) or (abs(eyeel)>25);
0 - for valid, blink=0 and abs(eyeaz)>25 and abs(eyeel)>25.

DXFData class:

Main function declaration:
int ReadDXFFile(CString fname, int noofpoints)

First, read the x,y,z dimension data for 12 planes.
Second, transfer Plane coordinates from dxf format to screen format.
Third, read the data points and transfer dxf format to screen format.

Plotting

This feature allows all valid data points to be plotted and displays the defined planes and the cues if it is a trial that has cues. The user can input the starting and stopping points and the speed. A "PLAY" button allows for the user to alter these parameters and re-plot the data as needed. The main frame for plotting is shown as Figure 3.

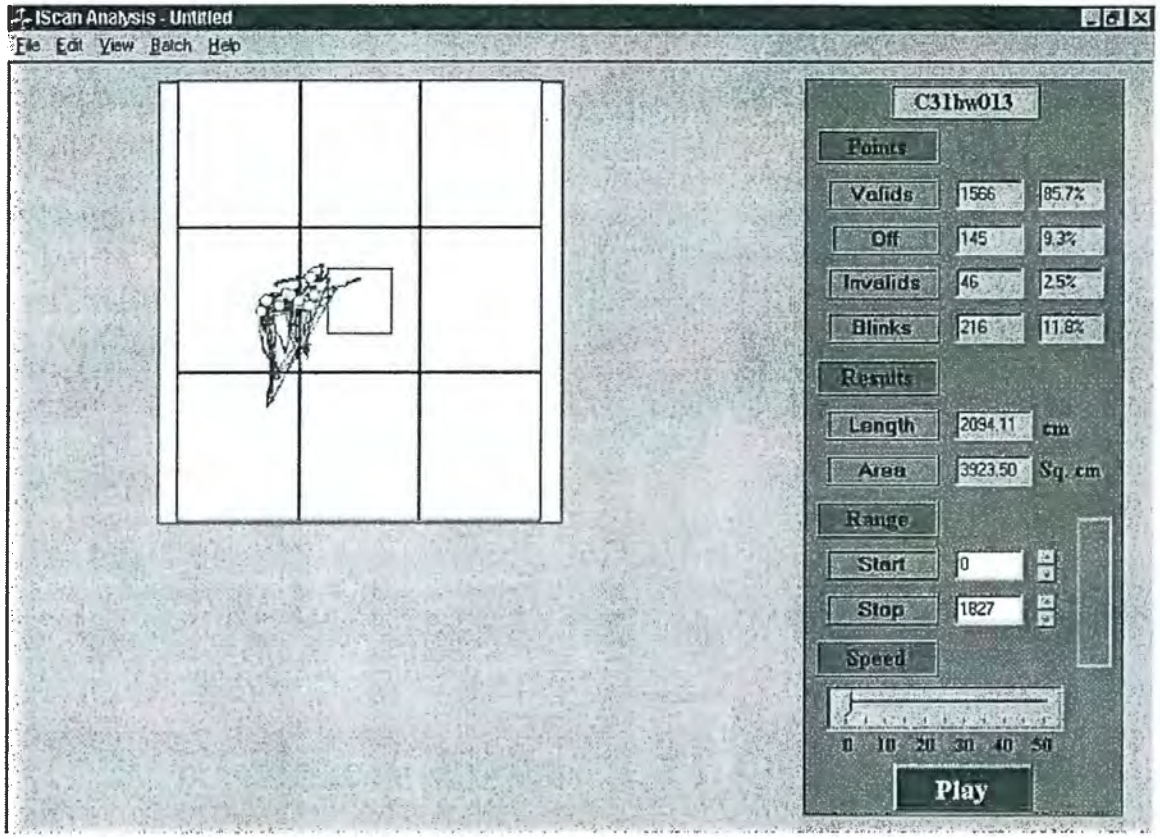
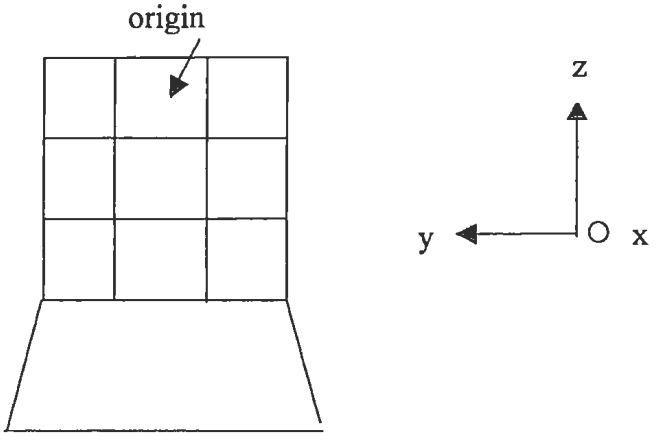


Figure 3. Main Frame for Plotting and Data Processing

Coordinate system:



Data Processing

The following variables are calculated in the program:

Length: the length of the eye movement path of valid data points, the total distance between two adjacent valid data points going sequentially through them. Function declaration in program: float IScanObject::GetLength().

Area: the area that includes all valid data points. The outer points were found by the convex hull algorithm and area calculated by triangularization. Function declaration in program: float IScanObject::GetArea(). The algorithm I used to calculate the area is Graham's Scan by convex hull. The detail implementation refers to class CClustArea in program. Given a set of points on the plane, Graham's scan computes their convex hull. The algorithm works in three phases:

1.Find an extreme point. This point will be the pivot, is guaranteed to be on the hull, and is chosen to be the point with largest y coordinate.

2.Sort the points in order of increasing angle about the pivot. We end up with a star-shaped polygon (one in which one special point, in this case the pivot, can "see" the whole polygon).

3.Build the hull, by marching around the star-shaped poly, adding edges when we make a left turn, and back-tracking when we make a right turn.

Clusters: Clustering analysis is to determine clusters, pairs, and singletons in eye-movement scan-path records. These are calculated by going sequentially through the valid data points and seeing if the next data point is within the radius set in the parameter file. If it is, it counts in the cluster and you move on to the next point to see if it is in the cluster as well. The radius check is to calculate the distance between two adjacent valid data points. If it is not, then the next point is its own cluster and you test it against the next point. The data given for each cluster includes the number of points in the cluster, the mean x and y position for that cluster and the duration. The total duration is calculated from the number of data points multiplied by the duration in the parameters section. The mean duration is the average duration of each data point. At least three data points make up a cluster. Otherwise it is a pair (two data points) or a singleton (one data point). The detail implementation refers to CClust class.

Fixations: Every coordinate (x,y) that has a cluster, pair or singleton in it, is then described as a fixation. A fixation may include several clusters, pairs or singletons since the fixation do not have be sequential in time. The x and y coordinates, the number of data points in that fixation and the cumulative fixation time (which is the sum of the durations for all the data points in that fixation) is given. The detail implementation refers to CCFT class.

Parameter Dialog Box

You can change parameters for Iscan through Parameter Dialog Box as shown in Figure 4. Radius is used for clustering. Duration represents the time interval for sampling data. MaxC is the number of most density clusters displayed in plotting screen, which are represented in purple cycles.

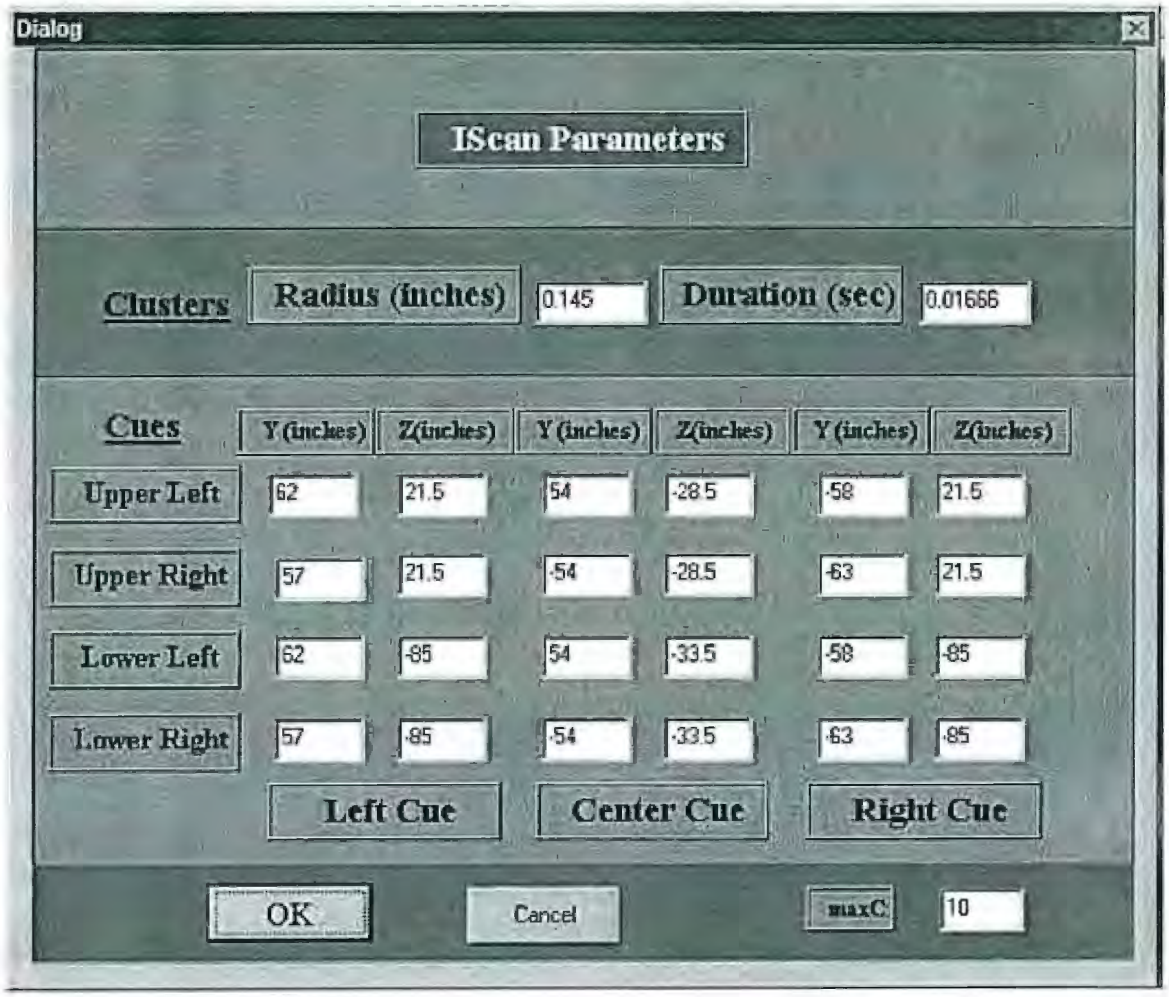


Figure 4. Parameter Dialog Box for Iscan

Output files

*.out

*.cls
A summary is given at the beginning of this file that includes the number of, number of points in and the percentage of points in clusters, pairs or singletons. A sample output file is shown in Figure 5.

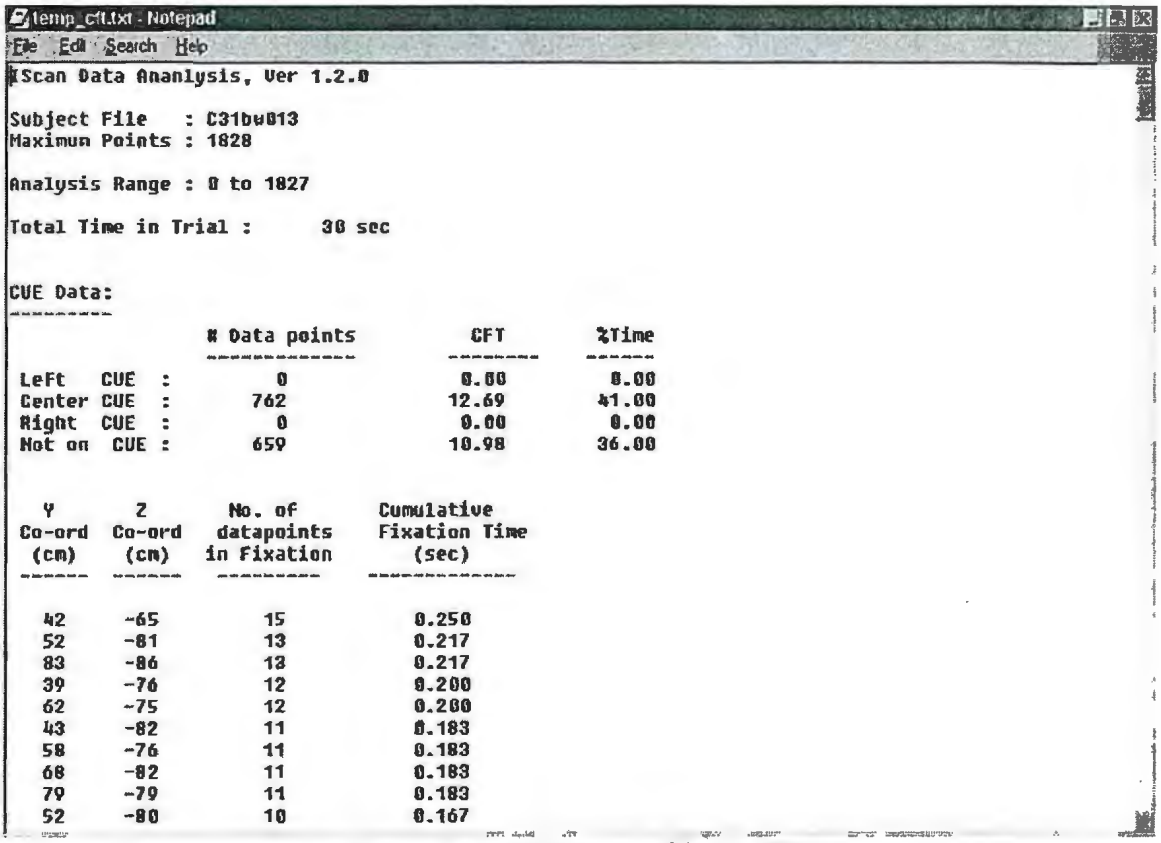
temp_clust.txt - Notepad

File Edit Search Help

```
IScan Data Ananlysis, Ver 1.2.0

Subject File   : C31bw013
Maximum Points : 1828

Analysis Range : 0 to 1827
Radius for Cluster/pair :     0.3683
Duration for each point :     0.0167

CLUSTERS, PAIRS OR SINGLETONS IN EYE-MOVEMENT RECORDS
-----------------------------------------------------

Summary :
-------

Number of Clusters : 95
          Pairs    : 176
          Singles  : 721

Number of Points in Clusters : 347
                     Pairs    : 352
                     Singles  : 721

Percentage of Fixations in Clusters : 24.4
                            Pairs    : 24.8
                            Singles  : 50.8
CLUSTERS :
--------
 Number of     Y       Z        Total
 datapoints   Mean    Mean     Duration
              (cm)    (cm)       (sec)
 ----------   ----    ----      ------
     3         53     -64       0.050
     3         72     -69       0.050
     4         27     -68       0.067
```

Figure 5. Cluster File for Iscan

*.cft



temp_cft.txt - Notepad

File Edit Search Help

```
IScan Data Ananlysis, Ver 1.2.0

Subject File   : C31bw013
Maximun Points : 1828

Analysis Range : 0 to 1827

Total Time in Trial :      30 sec


CUE Data:
---------
                  # Data points          CFT        %Time
                  --------------        -------     ------
 LeFt   CUE  :          0                0.00        0.00
 Center CUE  :        762               12.69       41.00
 Right  CUE  :          0                0.00        0.00
 Not on  CUE :        659               10.98       36.00


   Y       Z       No. of       Cumulative
 Co-ord  Co-ord   datapoints    Fixation Time
  (cm)    (cm)   in Fixation       (sec)
 ------  ------   ----------    --------------

   42     -65         15            0.250
   52     -81         13            0.217
   83     -86         13            0.217
   39     -76         12            0.200
   62     -75         12            0.200
   43     -82         11            0.183
   58     -76         11            0.183
   68     -82         11            0.183
   79     -79         11            0.183
   52     -80         10            0.167
```

Figure 6. Sample output file for CFT

*.xy

Batch Processing

This program has a batch processing files which lets you select multiple files for processing. The detail implementation is in void CMainFrame::OnBatch(). If you don't want to overwrite existing output files, please check Edit for Overwrite Files.

There are three kinds of error message when batch processing calls iscan = new IScanObject(files[i]):

1) Error opening file!

2) Unable to read RAW file Format!

3) No data points!

Appendix R

Validation for ISCAN Outcome Measures

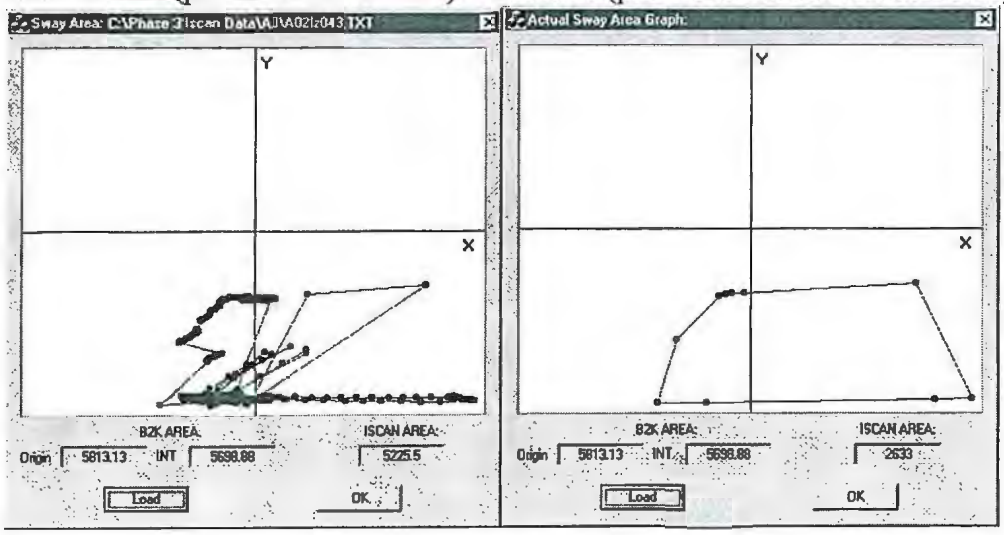
ISCAN Area Comparison (cm^2):

The check the area calculation in the ISCAN Analysis program, the area was calculated by hand, by the convex hull (Convex) method and by the modified convex hull method (ModCH) and by the same algorithm used in the postural sway analysis (B2K). It was decided that the modified convex hull algorithm would be used. A description of this method is described below.

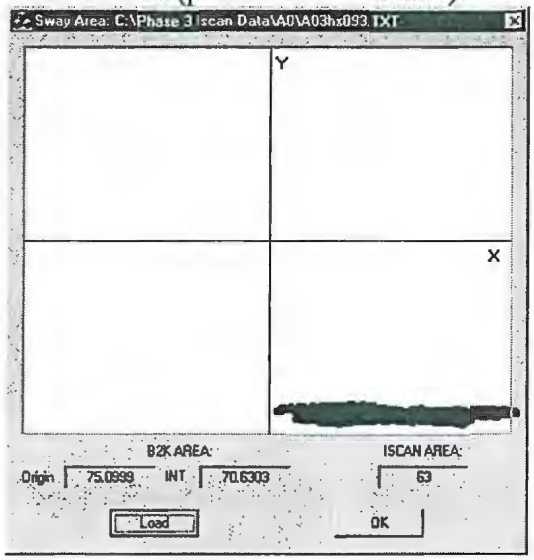
The convex hull method found the outermost points in the dataset. This resulted in finding a larger area than was actually covered by the eye movement path (please see the second figure of each set). To better describe the area, a modification to the convex hull area was added which went through the data point and alternated subtracting and adding areas until all data points were taken into account. A test was completed before subtracting to ensure that the area subtracted did not exceed the existing area. The following table describes the comparison of all methods.

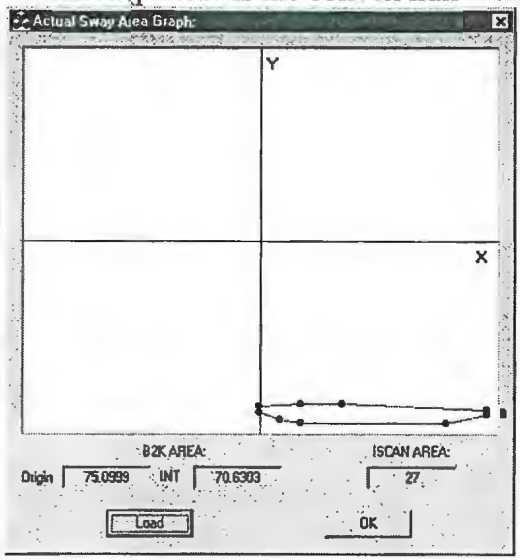
filename	°	load	task	cue	Hand	Convex (%)	ModCH(%)	B2K (%)
A02lz043	26	full	reach	yes	3,210	5,225 (63%)	2,633 (-17)	5,813 (81%)
A03hx093	14	half	stat	yes	39	63 (62%)	27 (-31%)	75 (92%)
B12bw013	0	none	stat	no	886	2,561 (189%)	740 (-16%)	3,276 (270%)
A34fy093	0	full	reach	no	1,397	3,170 (127%)	1,854 (33%)	3,240 (132%)
A37gz033	14	no	reach	yes	6,060	9,519 (57%)	2,775 (-54%)	14,077 (132%)
A59kw033	26	half	stat	no	1,417	3,654 (158%)	2,957 (108%)	5,392 (281%)

Filename: A02lz043
Hand estimation: 3,210.17 cm^2
Convex Hull calculation: 5,225.5 cm^2 (63% error from the hand estimation)
Sachin's modified convex hull calculation: 2,633 cm^2 (-17% error from the hand estimation)
Convex hull (picture is the dataset): Sachin's (picture is the convex hull area):

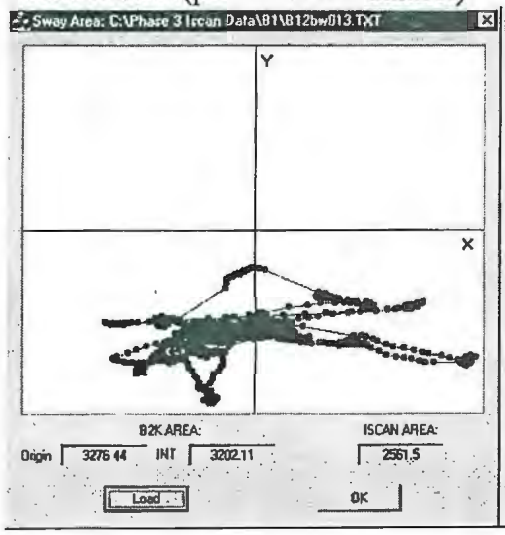


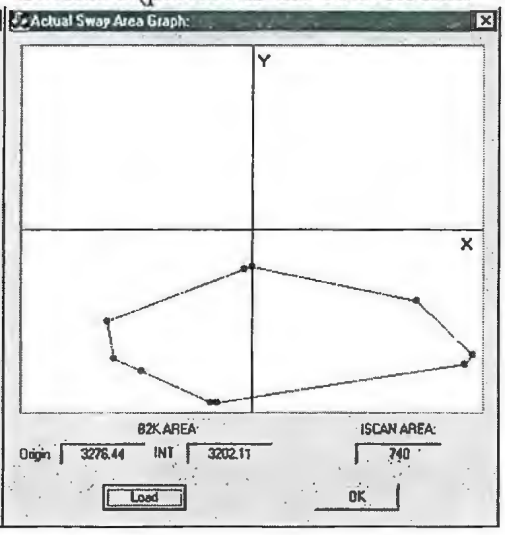
Filename: A03hx093
Hand estimation: 38.87 cm^2
Convex Hull calculation: 63 cm^2 (62 % error from the hand estimation)
Sachin's modified convex hull calculation: 27 cm^2 (-31% error from the hand estimation)
Convex hull (picture is the dataset): Sachin's (picture is the convex hull area):



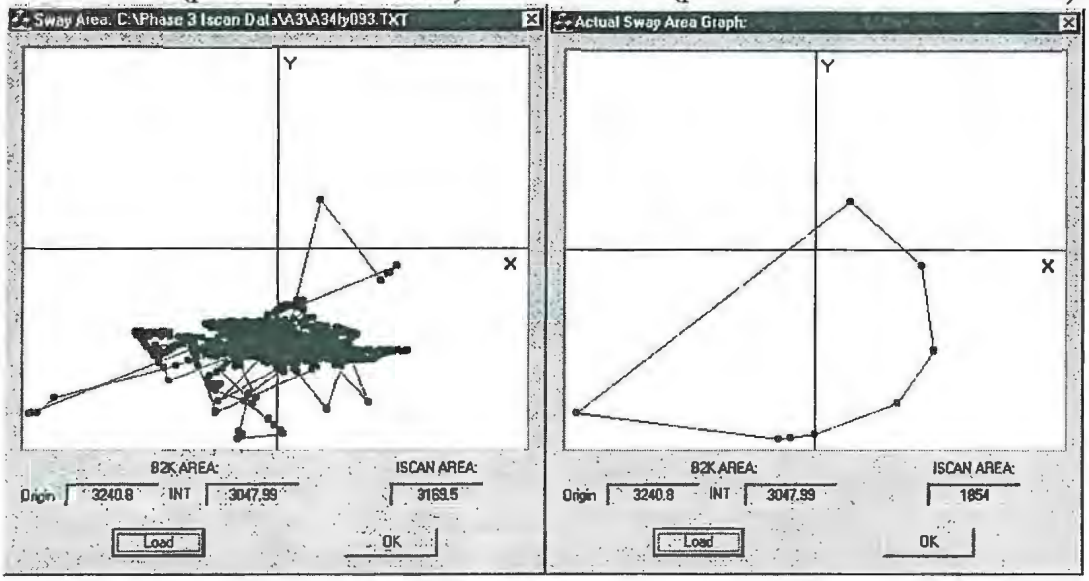


Filename: B12bw013
Hand estimation: 885.46 cm^2
Convex Hull calculation: 2561.5 cm^2 (189 % error from the hand estimation)
Sachin's modified convex hull calculation: 740 cm^2 (-16% error from the hand estimation)
Convex Hull (picture is the dataset): Sachin's (picture is the convex hull area):

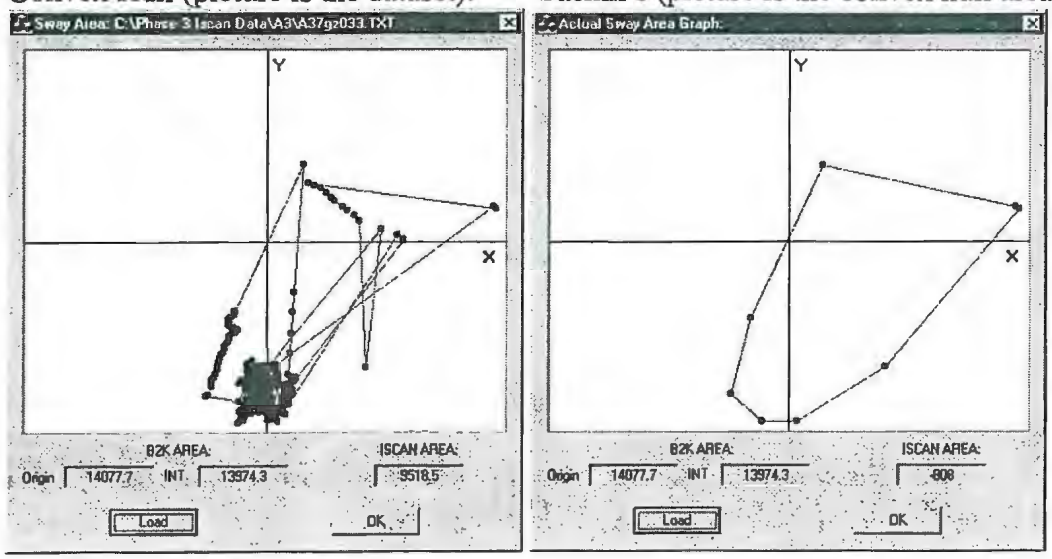




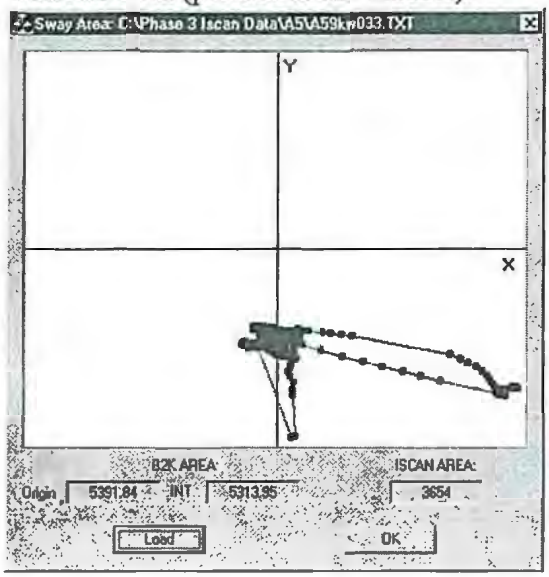
Filename: A34fy093
Hand estimation: 1,396.5 cm^2
Convex Hull calculation: 3,169.5 cm^2 (127 % error from the hand estimation)
Sachin's modified convex hull calculation: 1,854 cm^2 (33 % error from the hand estimation)
Convex Hull (picture is the dataset): Sachin's (picture is the convex hull area):

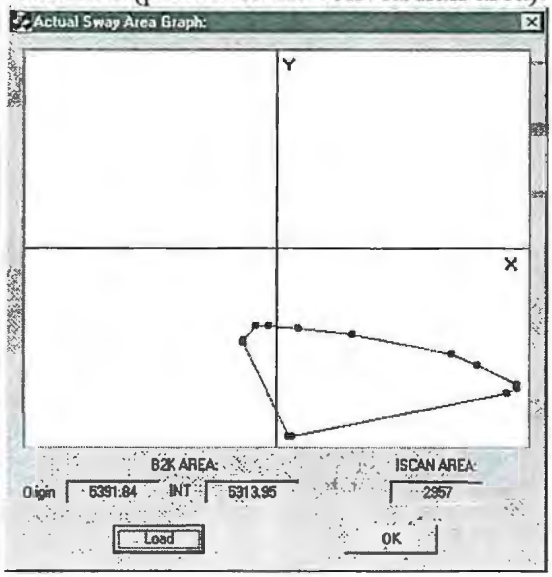


Filename: A37gz033
Hand estimation: 6,060 cm^2 (or 7,189 with section)
Convex Hull calculation: 9,518.5 cm^2 (57% error from the hand estimation)
Sachin's modified convex hull calculation: -808 cm^2 (---- % error from the hand estimation)
Convex Hull (picture is the dataset): Sachin's (picture is the convex hull area):



Filename: A59kw033
Hand estimation: 1,416.88 cm^2
Convex Hull calculation: 3,654 cm^2 (158% error from the hand estimation)
Sachin's modified convex hull calculation: 2,957 cm^2 (108% error from the hand estimation)
Convex Hull (picture is the dataset): Sachin's (picture is the convex hull area):





Eye Length Comparison (cm):

To test the length calculation in the ISCAN Analysis software, the valid ISCAN data was imported into EXCEL. The following procedure for calculating length was used in excel and in the ISCAN Analysis software:

Taking the distance between each point starting with the first point to the second, and summing all the distances.

$$\text{Length} = \Sigma\sqrt{(x_2-x_1)^2 + (y_2-y_1)^2}$$

The following table shows that no difference between the ISCAN and EXCEL calculations exists and therefore, the ISCAN Analysis length is valid.

filename	°	load	task	cue	Excel	ISCAN
A02lz043	26	full	reach	yes	1266.22	1266.22
A03hx093	14	half	stat	yes	397.84	397.84
B12bw013	0	none	stat	no	1058.62	1058.62
A34fy093	0	full	reach	no	1836.31	1836.31
A37gz033	14	no	reach	yes	2060.80	2060.80
A59kw033	26	half	stat	no	871.34	871.34

Appendix S

EMG and Postural Sway Analysis

Table S-1. Range of P-values for testing the effects of experience, load, task, inclination and visual cue in the Structural Equation Model for EMG at the 95th percentile and Postural Sway Outcomes.

Experimental Condition or Independent Variable	**LG**	**LH**	**LQ**	**LT**	**RG**	**RH**	**RQ**	**RT**	**Sway Area**	**Sway Length**	**Excursion in the X direction**	**Excursion in the Y direction**
Range of R Square Values	0.289	0.407	0.079	0.634	0.297-0.299	0.382	0.093	0.653	0.756-0.758	0.67-0.672	0.540	0.755
Work Experience Variables:												
Experienced vs. Inexperienced	**0.004**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	0.12	**0.0001**	0.56	0.99	0.99
Months of Work Experience	0.84	**0.0001**	**0.008**	**0.0001**	0.94	**0.001**	**0.0001**	**0.05**	0.99	0.98	0.93	0.94
Hours of Work Activity	0.83	**0.0001**	**0.0001**	**0.0002**	0.99	**0.0001**	**0.0001**	**0.01**	0.99	0.98	0.98	0.94
Load Variables:												
Fatiguing Task Performed (Full vs. Half vs. None)	0.78	0.15-0.16	0.48	0.63-0.64	0.26-0.27	0.92-0.93	0.3	0.53-0.54	0.9-0.91	0.93-0.96	0.77	0.97-0.99
Experimental Conditions:												
Task (Reach vs. Stationary)	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Inclination (0 vs. 14 vs. 26 degrees)	**0.02**	**0.0002-0.0003**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.013-0.006**
Visual Cue	0.43-0.45	0.16	0.68	0.32	0.13	0.097	0.11	0.22	0.24-0.25	0.08-0.1	0.4	0.1-0.11

Experimental Condition or Independent Variable	LG	LH	LQ	LT	RG	RH	RQ	RT	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Interactions of Experience Variables												
Experience * Hamstring muscle activity		0.0001				0.0001						
Experience * Task										0.025		
Months of work experience * Tibialis muscle activity				0.0017								
Months of work experience * Hamstring muscle activity		0.0001				0.0023						
Hours of work activity * Hamstring muscle activity		0.0001				0.0001						
Hours of work activity * Incline				0.034								
Interactions of Experimental Conditions												
Task * Incline		0.0003-0.0004				0.0001			0.0001	0.0002-0.001	0.0001	0.0001

Table S-2. Least Square Means for EMG and postural sway variables for the median of the three SEM's at the 95%ile

Left Gastrocnemius (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	16.63	1.14
Exp1	12.66	1.15
Task reach	24.66	1.10
Task stat	8.77	1.10
Incline 0	13.72	1.10
Incline14	14.34	1.10
Incline 26	16.15	1.10
Cue no	14.92	1.10
Cue yes	14.49	1.10
Load full	15.04	1.10
Load half	15.01	1.10
Load none	14.08	1.10

Right Gastrocnemius (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	18.39	1.15
Exp1	9.63	1.17
Task reach	24.14	1.12
Task stat	7.69	1.12
Incline 0	12.73	1.12
Incline14	12.64	1.12
Incline 26	15.73	1.12
Cue no	14.04	1.12
Cue yes	13.23	1.12
Load full	13.79	1.12
Load half	14.03	1.12
Load none	13.08	1.12

Left Tibialis (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	8.99	1.12
Exp1	6.68	1.13
Task reach	9.13	1.09
Task stat	6.72	1.09
Incline 0	2.26	1.10
Incline14	5.87	1.10
Incline 26	36.31	1.09
Cue no	8.04	1.09
Cue yes	7.63	1.09
Load full	7.83	1.10
Load half	8.08	1.10
Load none	7.60	1.10

Right Tibialis (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	10.16	1.20
Exp1	8.30	1.22
Task reach	10.74	1.19
Task stat	8.16	1.19
Incline 0	2.60	1.19
Incline14	6.89	1.19
Incline 26	45.74	1.19
Cue no	9.60	1.19
Cue yes	9.12	1.19
Load full	8.92	1.11
Load half	8.87	1.11
Load none	10.36	1.53

Left Quadricep (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	5.80	1.17
Exp1	5.29	1.19
Task reach	5.89	1.14
Task stat	5.25	1.14
Incline 0	4.36	1.14
Incline14	5.65	1.14
Incline 26	6.98	1.14
Cue no	5.57	1.14
Cue yes	5.55	1.14
Load full	5.19	1.09
Load half	5.46	1.09
Load none	6.06	1.36

Right Quadricep (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	5.59	1.23
Exp1	5.43	1.25
Task reach	6.05	1.20
Task stat	5.03	1.19
Incline 0	3.86	1.20
Incline14	6.14	1.20
Incline 26	7.08	1.20
Cue no	5.72	1.19
Cue yes	5.32	1.19
Load full	5.65	1.13
Load half	5.98	1.13
Load none	4.97	1.51

Left Hamstring (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	5.89	1.15
Exp1	5.86	1.17
Task reach	11.50	1.10
Task stat	3.05	1.10
Incline 0	5.84	1.11
Incline14	5.75	1.11
Incline 26	6.18	1.10
Cue no	5.98	1.10
Cue yes	5.86	1.10
Load full	6.01	1.11
Load half	6.12	1.10
Load none	5.64	1.10
task (reach)*incline(0)	11.76	1.11
task (reach)*incline(14)	11.99	1.11
task (reach)*incline(26)	10.79	1.11
task (stationary)*incline(0)	2.90	1.11
task (stationary)*incline(14)	2.76	1.11
task (stationary)*incline(26)	3.54	1.11

Right Hamstring (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	6.04	1.17
Exp1	7.06	1.17
Task reach	13.15	1.11
Task stat	3.47	1.11
Incline 0	6.41	1.11
Incline14	6.30	1.11
Incline 26	7.64	1.11
Cue no	6.74	1.11
Cue yes	6.77	1.11
Load full	6.85	1.11
Load half	6.79	1.11
Load none	6.64	1.11
task (reach)*incline(0)	14.17	1.11
task (reach)*incline(14)	12.59	1.11
task (reach)*incline(26)	12.75	1.11
task (stationary)*incline(0)	2.90	1.11
task (stationary)*incline(14)	3.16	1.11
task (stationary)*incline(26)	4.58	1.11

Sway Area (cm^2)	Geometric Mean	Geometric Std. Error
Exp0	6.57	1.06
Exp1	7.39	1.07
Task reach	15.43	1.05
Task stat	3.11	1.05
Incline 0	6.04	1.05
Incline14	6.98	1.05
Incline 26	7.87	1.05
Cue no	7.11	1.05
Cue yes	6.74	1.05
Load full	6.90	1.05
Load half	6.90	1.05
Load none	6.97	1.05
task (reach)*incline(0)	15.75	1.06
task (reach)*incline(14)	15.55	1.06
task (reach)*incline(26)	14.98	1.06
task (stationary)*incline(0)	2.32	1.06
task (stationary)*incline(14)	3.13	1.06
task (stationary)*incline(26)	4.13	1.06

Sway Length (cm)	Geometric Mean	Geometric Std. Error
Exp0	66.49	1.03
Exp1	74.75	1.04
Task reach	102.75	1.03
Task stat	47.63	1.03
Incline 0	59.81	1.03
Incline14	69.21	1.03
Incline 26	82.70	1.03
Cue no	71.76	1.03
Cue yes	68.20	1.03
Load full	70.72	1.03
Load half	69.80	1.03
Load none	69.35	1.03
task (reach)*incline(0)	95.06	1.03
task (reach)*incline(14)	103.14	1.03
task (reach)*incline(26)	110.64	1.03
task (stationary)*incline(0)	37.63	1.03
task (stationary)*incline(14)	46.45	1.03
task (stationary)*incline(26)	61.81	1.03
task (reach)*EXP(0)	100.07	1.04
task (reach)*EXP(1)	106.66	1.04
task (stationary)*EXP(0)	44.17	1.03
task (stationary)*EXP(0)	52.38	1.04

Medio/Lateral Excursion (X, cm)	Geometric Mean	Geometric Std. Error
Exp0	2.35	1.05
Exp1	2.53	1.05
Task reach	3.67	1.04
Task stat	1.62	1.04
Incline 0	2.06	1.04
Incline14	2.45	1.04
Incline 26	2.86	1.04
Cue no	2.45	1.04
Cue yes	2.42	1.04
Load full	2.44	1.04
Load half	2.41	1.04
Load none	2.46	1.04
task (reach)*incline(0)	3.42	1.04
task (reach)*incline(14)	3.66	1.04
task (reach)*incline(26)	3.97	1.04
task (stationary)*incline(0)	1.24	1.04
task (stationary)*incline(14)	1.64	1.04
task (stationary)*incline(26)	2.07	1.04

Anterior/Posterior Excursion (Y, cm)	Geometric Mean	Geometric Std. Error
Exp0	4.71	1.04
Exp1	4.92	1.04
Task reach	7.65	1.03
Task stat	3.01	1.03
Incline 0	4.80	1.03
Incline14	4.76	1.03
Incline 26	4.83	1.03
Cue no	4.87	1.03
Cue yes	4.72	1.03
Load full	4.83	1.03
Load half	4.81	1.03
Load none	4.76	1.03
task (reach)*incline(0)	8.16	1.03
task (reach)*incline(14)	7.82	1.03
task (reach)*incline(26)	7.01	1.03
task (stationary)*incline(0)	2.83	1.03
task (stationary)*incline(14)	2.90	1.03
task (stationary)*incline(26)	3.33	1.03

Table S-3. P-values for Significant Effect of EMG on Postural Sway from 95%ile Structural Models with Experience/Inexperienced, Months of job experience and Hours of Work Activity (parenthesis indicate the number of models the variable was significant in).

Experimental Condition or Independent Variable	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Left Gastrocnemius				**0.0001** (3)
Left Hamstring	**0.0001** (3)	**0.0001-0.003** (3)		

Table S-4. Range of P-values for testing the effects of experience, load, task, inclination and visual cue in the Structural Equation Model for EMG at the 75th percentile and Postural Sway Outcomes.

Experimental Condition or Independent Variable	LG	LH	LQ	LT	RG	RH	RQ	RT	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Range of R-square values	0.063-0.068	0.147-0.150	0.092-0.093	0.598-0.600	0.068-0.073	0.136-0.137	0.083-0.089	0.663-0.669	0.746-0.749	0.661-0.667	0.539	0.738-0.743
Work Experience Variables:												
Experienced vs. Inexperienced	**0.0001**	0.99	0.50	**0.0001**	0.08	0.96	**0.0001**	0.18	0.25	0.12	0.48	0.99
Years of Work Experience	0.08	0.99	0.14	**0.0001**	0.12	0.96	**0.0001**	**0.002**	**0.0001**	0.95	0.97	0.99
Hours of Work Activity	**0.0001**	0.80	0.65	**0.0001**	0.99	0.98	**0.0001**	0.23	0.87	0.99	0.56	0.93
Load Variables:												
Fatiguing Task Performed (Full vs. Half vs. None)	0.62-0.63	0.57-0.68	0.07-0.10	0.68-0.69	0.37-0.41	0.90-0.97	**0.03-0.04**	0.44-0.52	0.76-0.86	0.72-0.87	0.80-0.89	0.78-0.93
Experimental Conditions:												
Task (Reach vs. Stationary)	**0.0001**	**0.0001**	**0.009-0.027**	**0.04**	**0.0001**	**0.0001**	**0.034-0.043**	**0.004-**0.06	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Inclination (0 vs. 14 vs. 26 degrees)	**0.007-**0.096	**0.0071-0.015**	**0.0001**	**0.0001**	0.078-0.22	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Visual Cue	0.29-0.36	0.30-0.35	0.83-0.85	0.42-0.44	0.26-0.29	0.29-0.30	0.23-0.30	0.23-0.26	0.12-0.15	0.05-0.09	0.78-0.86	0.10 0.17

Experimental Condition or Independent Variable	LG	LH	LQ	LT	RG	RH	RQ	RT	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Interactions of Work Experience Variables:												
Experience*Incline	0.027				0.0021			0.0006				
Experience * Task						0.034		0.029	0.009	0.027		0.0036
Months of work experience*Incline				0.0001	0.0073							
Months of work experience * Gastrocnemius muscle activity					0.0041							
Hours of work activity * Gastrocnemius muscle activity			0.0001									
Hours of work activity * Quadriceps muscle activity			0.013	0.0001								
Hours of work activity * Incline	0.0024						0.0100	0.0001				
Interactions of Experimental Conditions:												
Task * Incline		0.016-0.029 (3)	0.036-0.039 (3)			0.023-0.035 (3)			0.0001 (3)	0.0001 (3)	0.0001 (3)	0.0001 (3)
Task * Cue											0.013-0.044 (3)	

Table S-5. Least Square Means for EMG and postural sway variables for the median of the three SEM's at the 75%ile

Left Gastrocnemius (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	6.50	1.14
Exp1	5.14	1.16
Task reach	7.08	1.11
Task stat	4.72	1.11
Incline 0	6.15	1.11
Incline14	5.67	1.11
Incline 26	5.51	1.11
Cue no	5.92	1.11
Cue yes	5.65	1.11
Load full	5.97	1.11
Load half	5.80	1.11
Load none	5.59	1.11
incline (0)*EXP(0)	7.21	1.15
incline (0)*EXP(1)	5.26	1.16
incline (14)*EXP(0)	6.09	1.15
incline (14)*EXP(1)	5.33	1.17
incline (26)*EXP(0)	6.25	1.15
incline (26)*EXP(1)	4.86	1.17

Right Gastrocnemius (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	5.70	1.13
Exp1	4.87	1.14
Task reach	6.67	1.08
Task stat	4.20	1.08
Incline 0	5.70	1.08
Incline14	5.00	1.09
Incline 26	5.22	1.08
Cue no	5.49	1.08
Cue yes	5.10	1.08
Load full	5.47	1.08
Load half	5.32	1.08
Load none	5.09	1.08
incline (0)*EXP(0)	5.78	1.13
incline (0)*EXP(1)	5.61	1.14
incline (14)*EXP(0)	5.45	1.13
incline (14)*EXP(1)	4.59	1.14
incline (26)*EXP(0)	5.87	1.13
incline (26)*EXP(1)	4.49	1.14

Left Tibialis (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	4.36	1.13
Exp1	3.97	1.14
Task reach	4.31	1.09
Task stat	4.04	1.09
Incline 0	1.41	1.09
Incline14	2.70	1.09
Incline 26	19.04	1.09
Cue no	4.25	1.09
Cue yes	4.09	1.09
Load full	4.29	1.09
Load half	4.21	1.09
Load none	4.01	1.09

Right Tibialis (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	5.05	1.12
Exp1	4.64	1.14
Task reach	4.89	1.09
Task stat	4.79	1.09
Incline 0	1.53	1.09
Incline14	3.00	1.10
Incline 26	24.60	1.09
Cue no	4.96	1.09
Cue yes	4.72	1.09
Load full	4.85	1.09
Load half	4.83	1.09
Load none	4.83	1.09
incline (0)*EXP(0)	1.54	1.12
incline (0)*EXP(1)	1.52	1.14
incline (14)*EXP(0)	3.60	1.12
incline (14)*EXP(1)	2.50	1.14
incline (26)*EXP(0)	23.22	1.12
incline (26)*EXP(1)	26.18	1.14
task (reach)*EXP(0)	5.35	1.12
task (reach)*EXP(1)	4.47	1.14
task (stationary)*EXP(0)	4.76	1.12
task (stationary)*EXP(1)	4.81	1.14

Left Quadricep (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	3.60	1.18
Exp1	3.25	1.20
Task reach	3.51	1.15
Task stat	3.32	1.15
Incline 0	2.62	1.15
Incline14	3.59	1.15
Incline 26	4.21	1.15
Cue no	3.39	1.15
Cue yes	3.43	1.15
Load full	3.19	1.09
Load half	3.45	1.09
Load none	3.60	1.41
task (reach)*incline(0)	2.84	1.16
task (reach)*incline(14)	3.77	1.16
task (reach)*incline(26)	4.04	1.16
task (stationary)*incline(0)	2.42	1.15
task (stationary)*incline(14)	3.43	1.15
task (stationary)*incline(26)	4.39	1.16

Left Quadricep (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	3.35	1.23
Exp1	3.56	1.25
Task reach	3.56	1.21
Task stat	3.25	1.21
Incline 0	2.44	1.21
Incline14	3.68	1.21
Incline 26	4.39	1.21
Cue no	3.48	1.21
Cue yes	3.33	1.21
Load full	3.23	1.15
Load half	3.54	1.15
Load none	3.44	1.52

Left Hamstring (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	2.87	1.29
Exp1	2.39	1.34
Task reach	3.98	1.29
Task stat	2.04	1.29
Incline 0	2.84	1.29
Incline14	2.77	1.29
Incline 26	2.95	1.29
Cue no	2.88	1.29
Cue yes	2.82	1.29
Load full	2.93	1.29
Load half	2.91	1.29
Load none	2.71	1.29
task (reach)*incline(0)	4.07	1.29
task (reach)*incline(14)	4.02	1.29
task (reach)*incline(26)	3.85	1.29
task (stationary)*incline(0)	1.98	1.29
task (stationary)*incline(14)	1.90	1.29
task (stationary)*incline(26)	2.26	1.29

Right Hamstring (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	3.24	1.16
Exp1	2.83	1.18
Task reach	4.13	1.12
Task stat	2.24	1.12
Incline 0	2.63	1.12
Incline14	2.86	1.12
Incline 26	3.75	1.12
Cue no	3.01	1.12
Cue yes	3.08	1.12
Load full	3.06	1.12
Load half	3.05	1.12
Load none	3.02	1.12
task (reach)*EXP(0)	4.58	1.17
task (reach)*EXP(1)	3.67	1.18
task (stationary)*EXP(0)	2.30	1.17
task (stationary)*EXP(1)	2.19	1.18
task (reach)*incline(0)	3.65	1.12
task (reach)*incline(14)	4.03	1.12
task (reach)*incline(26)	4.78	1.12
task (stationary)*incline(0)	1.89	1.12
task (stationary)*incline(14)	2.03	1.12
task (stationary)*incline(26)	2.94	1.12

Sway Area (cm^2)	Geometric Mean	Geometric Std. Error
Exp0	6.27	1.07
Exp1	7.01	1.07
Task reach	16.84	1.06
Task stat	2.71	1.06
Incline 0	5.86	1.06
Incline14	6.71	1.06
Incline 26	7.79	1.06
Cue no	6.95	1.06
Cue yes	6.54	1.06
Load full	6.76	1.06
Load half	6.75	1.06
Load none	6.72	1.06
task (reach)*EXP(0)	15.65	1.07
task (reach)*EXP(1)	16.86	1.08
task (stationary)*EXP(0)	2.51	1.07
task (stationary)*EXP(1)	2.92	1.08
task (reach)*incline(0)	17.05	1.07
task (reach)*incline(14)	17.12	1.07
task (reach)*incline(26)	16.36	1.07
task (stationary)*incline(0)	2.02	1.07
task (stationary)*incline(14)	2.68	1.06
task (stationary)*incline(26)	3.71	1.07

Sway Length (cm)	Geometric Mean	Geometric Std. Error
Exp0	64.23	1.06
Exp1	71.97	1.07
Task reach	108.16	1.02
Task stat	45.50	1.26
Incline 0	59.82	1.02
Incline14	69.28	1.03
Incline 26	83.31	1.02
Cue no	72.08	1.02
Cue yes	68.28	1.02
Load full	71.05	1.02
Load half	70.11	1.02
Load none	69.31	1.02
task (reach)*incline(0)	100.06	1.03
task (reach)*incline(14)	108.91	1.03
task (reach)*incline(26)	116.11	1.03
task (stationary)*incline(0)	35.76	1.03
task (stationary)*incline(14)	44.07	1.03
task (stationary)*incline(26)	59.79	1.03
task (reach)*EXP(0)	101.30	1.06
task (reach)*EXP(1)	106.95	1.07
task (stationary)*EXP(0)	40.72	1.06
task (stationary)*EXP(1)	48.43	1.07

Medio/Lateral Excursion (X, cm)	Geometric Mean	Geometric Std. Error
Exp0	2.32	1.04
Exp1	2.57	1.05
Task reach	3.67	1.04
Task stat	1.61	1.04
Incline 0	2.06	1.04
Incline14	2.45	1.04
Incline 26	2.86	1.04
Cue no	2.45	1.04
Cue yes	2.42	1.04
Load full	2.44	1.04
Load half	2.41	1.04
Load none	2.45	1.04
task (reach)*incline(0)	3.42	1.04
task (reach)*incline(14)	3.65	1.04
task (reach)*incline(26)	3.96	1.04
task (stationary)*incline(0)	1.24	1.04
task (stationary)*incline(14)	1.64	1.04
task (stationary)*incline(26)	2.07	1.04
task (reach) * cue (no)	3.63	1.04
task (reach) * cue (yes)	3.51	1.04
task (stationary) * cue (no)	1.56	1.04
task (stationary) * cue (yes)	1.58	1.04

Anterior/Posterior Excursion (Y, cm)	Geometric Mean	Geometric Std. Error
Exp0	5.02	1.06
Exp1	4.93	1.06
Task reach	8.21	1.03
Task stat	2.89	1.03
Incline 0	4.83	1.03
Incline14	4.82	1.03
Incline 26	4.95	1.03
Cue no	4.95	1.03
Cue yes	4.78	1.03
Load full	4.91	1.03
Load half	4.89	1.03
Load none	4.80	1.03
task (reach)*incline(0)	8.67	1.03
task (reach)*incline(14)	8.38	1.03
task (reach)*incline(26)	7.61	1.03
task (stationary)*incline(0)	2.69	1.03
task (stationary)*incline(14)	2.78	1.03
task (stationary)*incline(26)	3.22	1.03
task (reach)*EXP(0)	8.63	1.06
task (reach)*EXP(1)	8.15	1.06
task (stationary)*EXP(0)	2.92	1.06
task (stationary)*EXP(1)	2.98	1.06

Table S-6. P-values for Significant Effect of EMG on Postural Sway from 75%ile Structural Models with Experience/Inexperienced, Months of job experience and Hours of Work Activity (parenthesis indicate the Number of models the variable was significant in).

Experimental Condition or Independent Variable	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Left Gastrocnemius	**0.0001** (1)			
Right Gastrocnemius	**0.0001** (2)	**0.0001** (1)		**0.0001** (1)
Right Hamstring		**0.0001** (1)		

Table S-7. Range of P-values for testing the effects of experience, load, task, inclination and visual cue in the Structural Equation Model for EMG at the 50th percentile and Postural Sway Outcomes.

Experimental Condition or Independent Variable	LG	LH	LQ	LT	RG	RH	RQ	RT	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Range of R-square values	0.038-0.041	0.045	0.093-0.094	0.518-0.519	0.041-0.048	0.067-0.072	0.071-0.075	0.587-0.616	0.746-0.748	0.663-0.666	0.539-0.540	0.741-0.742
Work Experience Variables:												
Experienced vs. Inexperienced	0.99	0.99	0.094	**0.0001**	0.79	0.99	**0.026**	0.14	0.99	0.086	0.65	**0.035**
Years of Work Experience	0.99	**0.0001**	**0.00038**	**0.0001**	0.99	**0.0001**	**0.0017**	**0.041**	0.049	0.43	0.99	0.99
Hours of Work Activity	**0.0001**	0.36	**0.00033**	**0.0001**	0.97	0.86	**0.0001**	0.96	0.89	0.36	0.99	0.97
Load Variables:												
Fatiguing Task Performed (Full vs. Half vs. None)	0.16-0.17	0.44-0.45	0.070-0.103	0.74 0.75	0.12-0.15	0.40-0.41	**0.0033-0.0048**	0.99	0.79-0.90	0.83-0.99	0.79-0.90	0.78-0.98
Experimental Conditions:												
Task (Reach vs. Stationary)	**0.0001**	**0.0001**	0.30-0.35	0.96-0.97	**0.0001**	**0.0001**	0.41-0.46	0.81-0.84	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Inclination (0 vs. 14 vs. 26 degrees)	**0.0004-0.051**	**0.005-0.007**	**0.0001**	**0.0001**	0.10-0.99	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001-0.0004**
Visual Cue	0.38-0.39	0.20-0.21	0.81-0.83	0.58-0.60	0.53-0.54	0.27-0.28	0.41-0.42	0.37-0.43	0.10	0.05-0.06	0.81-0.84	0.12-0.13

Experimental Condition or Independent Variable	LG	LH	LQ	LT	RG	RH	RQ	RT	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Interactions of Work Experience Variables:												
Experience* Incline					0.014	0.014		0.0002				
Experience * Task									0.0057	0.0009		0.0014
Months of work experience * Incline	0.0001			0.0001	0.0001			0.037				
Hours of work activity * Gastrocnemius muscle activity					0.0015							
Hours of work activity * Incline			0.0008			0.0007	0.0027	0.0001				
Interactions of Experimental Conditions:												
Task * Incline									0.0001 (3)	0.0001 (3)	0.0001 (3)	0.0001 (3)
Task * Cue											0.015-0.021 (3)	

Table S-8. Least Square Means for EMG and postural sway variables for the median of the three SEM's at the 50%ile

Left Gastrocnemius (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	3.68	1.23
Exp1	3.26	1.26
Task reach	3.83	1.22
Task stat	3.14	1.22
Incline 0	3.84	1.22
Incline14	3.30	1.22
Incline 26	3.29	1.22
Cue no	3.54	1.22
Cue yes	3.39	1.22
Load full	3.58	1.22
Load half	3.52	1.22
Load none	3.31	1.22

Right Gastrocnemius (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	2.83	1.12
Exp1	2.94	1.13
Task reach	3.29	1.07
Task stat	2.52	1.08
Incline 0	3.16	1.07
Incline14	2.80	1.08
Incline 26	2.70	1.08
Cue no	2.96	1.07
Cue yes	2.81	1.08
Load full	2.95	1.07
Load half	2.93	1.07
Load none	2.77	1.07
incline (0)*EXP(0)	2.84	1.12
incline (0)*EXP(1)	3.56	1.13
incline (14)*EXP(0)	2.91	1.12
incline (14)*EXP(1)	2.69	1.13
incline (26)*EXP(0)	2.75	1.12
incline (26)*EXP(1)	2.64	1.13

Left Tibialis (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	3.20	1.26
Exp1	2.63	1.29
Task reach	2.67	1.09
Task stat	2.95	1.09
Incline 0	1.20	1.09
Incline14	1.77	1.09
Incline 26	10.38	1.09
Cue no	2.81	1.09
Cue yes	2.80	1.09
Load full	2.81	1.09
Load half	2.83	1.09
Load none	2.78	1.09

Right Tibialis (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	3.65	1.13
Exp1	3.16	1.14
Task reach	3.27	1.10
Task stat	3.52	1.10
Incline 0	1.33	1.10
Incline14	2.02	1.10
Incline 26	14.22	1.10
Cue no	3.43	1.10
Cue yes	3.36	1.10
Load full	3.40	1.10
Load half	3.39	1.10
Load none	3.40	1.10
incline (0)*EXP(0)	1.40	1.13
incline (0)*EXP(1)	1.26	1.15
incline (14)*EXP(0)	2.51	1.13
incline (14)*EXP(1)	1.63	1.15
incline (26)*EXP(0)	13.80	1.13
incline (26)*EXP(1)	15.44	1.15

Left Quadricep (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	2.62	1.18
Exp1	1.96	1.19
Task reach	2.29	1.15
Task stat	2.28	1.15
Incline 0	1.77	1.15
Incline14	2.42	1.15
Incline 26	2.80	1.15
Cue no	2.29	1.15
Cue yes	2.29	1.15
Load full	2.31	1.09
Load half	2.45	1.09
Load none	2.11	1.40

Right Quadricep (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	2.60	1.35
Exp1	2.04	1.40
Task reach	2.31	1.35
Task stat	2.29	1.35
Incline 0	1.73	1.35
Incline14	2.47	1.35
Incline 26	2.84	1.35
Cue no	2.33	1.35
Cue yes	2.27	1.35
Load full	2.27	1.31
Load half	2.52	1.31
Load none	2.12	1.59

Left Hamstring (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.97	1.14
Exp1	1.77	1.16
Task reach	2.03	1.11
Task stat	1.59	1.11
Incline 0	1.74	1.11
Incline14	1.75	1.11
Incline 26	1.91	1.11
Cue no	1.83	1.11
Cue yes	1.76	1.11
Load full	1.83	1.11
Load half	1.81	1.11
Load none	1.74	1.11

Right Hamstring (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.92	1.27
Exp1	1.73	1.31
Task reach	2.05	1.26
Task stat	1.65	1.26
Incline 0	1.54	1.26
Incline14	1.73	1.26
Incline 26	2.33	1.26
Cue no	1.82	1.26
Cue yes	1.85	1.26
Load full	1.87	1.26
Load half	1.81	1.26
Load none	1.83	1.26
incline (0)*EXP(0)	1.56	1.27
incline (0)*EXP(1)	1.50	1.31
incline (14)*EXP(0)	1.81	1.27
incline (14)*EXP(1)	1.64	1.31
incline (26)*EXP(0)	2.51	1.27
incline (26)*EXP(1)	2.10	1.31

Sway Area (cm^2)	Geometric Mean	Geometric Std. Error
Exp0	6.47	1.07
Exp1	7.16	1.08
Task reach	16.99	1.06
Task stat	2.73	1.06
Incline 0	5.92	1.06
Incline14	6.79	1.06
Incline 26	7.86	1.06
Cue no	7.01	1.06
Cue yes	6.62	1.06
Load full	6.82	1.06
Load half	6.83	1.06
Load none	6.78	1.06
task (reach)*EXP(0)	16.33	1.07
task (reach)*EXP(1)	17.67	1.08
task (stationary)*EXP(0)	2.57	1.07
task (stationary)*EXP(1)	2.91	1.08
task (reach)*incline(0)	17.16	1.07
task (reach)*incline(14)	17.40	1.07
task (reach)*incline(26)	16.41	1.06
task (stationary)*incline(0)	2.04	1.07
task (stationary)*incline(14)	2.65	1.07
task (stationary)*incline(26)	3.75	1.06

Sway Length (cm)	Geometric Mean	Geometric Std. Error
Exp0	67.55	1.03
Exp1	75.23	1.03
Task reach	107.94	1.02
Task stat	45.42	1.02
Incline 0	59.73	1.03
Incline14	69.09	1.03
Incline 26	83.18	1.03
Cue no	71.95	1.02
Cue yes	68.14	1.02
Load full	70.90	1.03
Load half	69.97	1.03
Load none	69.20	1.03
task (reach)*incline(0)	99.89	1.03
task (reach)*incline(14)	108.65	1.03
task (reach)*incline(26)	115.90	1.03
task (stationary)*incline(0)	35.72	1.03
task (stationary)*incline(14)	44.00	1.06
task (stationary)*incline(26)	59.70	1.03
task (reach)*EXP(0)	106.46	1.03
task (reach)*EXP(1)	111.94	1.04
task (stationary)*EXP(0)	42.87	1.03
task (stationary)*EXP(1)	50.56	1.04

Medio/Lateral Excursion (X, cm)	Geometric Mean	Geometric Std. Error
Exp0	2.33	1.04
Exp1	2.57	1.05
Task reach	3.67	1.04
Task stat	1.61	1.04
Incline 0	2.06	1.04
Incline14	2.45	1.04
Incline 26	2.86	1.04
Cue no	2.45	1.04
Cue yes	2.42	1.04
Load full	2.44	1.04
Load half	2.41	1.04
Load none	2.45	1.04
task (reach)*incline(0)	3.42	1.04
task (reach)*incline(14)	3.66	1.04
task (reach)*incline(26)	3.96	1.04
task (stationary)*incline(0)	1.24	1.04
task (stationary)*incline(14)	1.64	1.04
task (stationary)*incline(26)	2.07	1.04
task (reach)*cue(no)	3.73	1.04
task (reach)*cue(yes)	3.62	1.04
task (stationary)*cue(no)	1.61	1.04
task (stationary)*cue(yes)	1.62	1.04

Anterior/Posterior Excursion (Y, cm)	Geometric Mean	Geometric Std. Error
Exp0	4.79	1.03
Exp1	4.80	1.04
Task reach	8.09	1.03
Task stat	2.84	1.03
Incline 0	4.77	1.03
Incline14	4.75	1.03
Incline 26	4.87	1.03
Cue no	4.87	1.03
Cue yes	4.71	1.03
Load full	4.84	1.03
Load half	4.81	1.03
Load none	4.73	1.03
task (reach)*incline(0)	8.58	1.03
task (reach)*incline(14)	8.24	1.03
task (reach)*incline(26)	7.49	1.03
task (stationary)*incline(0)	2.65	1.03
task (stationary)*incline(14)	2.73	1.03
task (stationary)*incline(26)	3.16	1.03
task (reach)*EXP(0)	8.23	1.03
task (reach)*EXP(1)	7.93	1.04
task (stationary)*EXP(0)	2.79	1.03
task (stationary)*EXP(1)	2.91	1.04

Table S-9. P-values for Significant Effect of EMG on Postural Sway from 50%ile Structural Models with Experience/Inexperienced, Months of job experience and Hours of Work Activity (parenthesis indicate the Number of models the variable was significant in).

Experimental Condition or Independent Variable	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Left Gastrocnemius	**0.0001** (1)	**0.0001-0.0002** (2)		**0.0001-0.0004** (3)
Right Gastrocnemius	**0.0001** (1)			
Right Quadricep				**0.018** (1)

Table S-10. Range of P-values for testing the effects of experience, load, task, inclination and visual cue in the Structural Equation Model for EMG at the 25th percentile and Postural Sway Outcomes.

Experimental Condition or Independent Variable	LG	LH	LQ	LT	RG	RH	RQ	RT	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Ranges of R-square values	0.051-0.053	0.027-0.031	0.075-0.076	0.405-0.407	0.042-0.052	0.054-0.066	0.059-0.061	0.434	0.746-0.750	0.661-0.666	0.538-0.539	0.741-0.743
Work Experience Variables:												
Experienced vs. Inexperienced	0.77	**0.0001**	**0.0001**	0.066	0.098	**0.043**	0.99	0.22	0.99	0.32	0.99	0.96
Years of Work Experience	**0.0001**	**0.018**	0.061	**0.0001**	0.14	0.98	**0.0002**	**0.025**	0.89	0.99	0.61	0.92
Hours of Work Activity	0.99	0.14	0.26	**0.0007**	0.77	0.071	**0.0001**	**0.0001**	0.91	0.97	0.98	0.99
Load Variables:												
Fatiguing Task Performed (Full vs. Half vs. None)	0.039-0.067	0.33-0.34	0.23-0.29	0.68-0.70	0.25-0.35	0.42-0.44	**0.007-0.008**	0.84	0.84-0.90	0.72-0.99	0.52-0.90	0.92-0.99
Experimental Conditions:												
Task (Reach vs. Stationary)	**0.0033-0.0038**	0.014-0.97	0.0001-0.87	0.52-0.86	**0.0001-0.019**	0.10-0.61	0.08-0.97	0.53-0.60	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Inclination (0 vs. 14 vs. 26 degrees)	**0.03-0.63**	**0.0013-0.0025**	**0.0001**	**0.0001**	**0.04-0.48**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001-0.0004**
Visual Cue	0.94-0.95	0.43-0.60	0.30-0.86	0.37-0.85	0.34-0.44	0.27-0.54	0.24-0.59	0.35-0.54	0.10-0.12	**0.03-0.05**	0.72-0.85	0.10-0.11

Experimental Condition or Independent Variable	LG	LH	LQ	LT	RG	RH	RQ	RT	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Interactions of Work Experience Variables:												
Experience* Incline		0.0078		0.0001	0.0001							
Experience * Task									0.0036	0.0004		0.0009
Months of work experience * Incline				0.0001	0.0026							
Months of work experience * Gastrocnemius muscle activity							0.0082					
Hours of work activity * Task												0.015
Hours of work activity * Quadriceps muscle activity				0.0009								
Hours of work activity * Incline	0.0069	0.0010			0.0004	0.0001	0.0053					
Months of work experience * Task					0.039							
Hours of work Activity * Hamstring muscle activity						0.0001						
Interactions of Experimental Conditions:												
Task * Incline				0.0025-0.0032 (2)				0.041-0.046 (3)	0.0001 (3)	0.0001 (3)	0.0001 (3)	0.0001 (3)
Task * Cue											0.015-0.017 (3)	

Table S-11. Least Square Means for EMG and postural sway variables for the median of the three SEM's at the 25%ile

Left Gastrocnemius (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.43	1.18
Exp1	1.61	1.20
Task reach	1.60	1.16
Task stat	1.44	1.16
Incline 0	1.68	1.16
Incline14	1.43	1.16
Incline 26	1.48	1.16
Cue no	1.51	1.16
Cue yes	1.53	1.16
Load full	2.10	2.10
Load half	2.03	1.09
Load none	0.82	1.47

Right Gastrocnemius (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.75	1.11
Exp1	1.74	1.12
Task reach	1.87	1.87
Task stat	1.63	1.63
Incline 0	1.92	1.08
Incline14	1.66	1.08
Incline 26	1.67	1.08
Cue no	1.79	1.08
Cue yes	1.70	1.08
Load full	1.78	1.08
Load half	1.76	1.08
Load none	1.70	1.08
incline (0)*EXP(0)	1.71	1.12
incline (0)*EXP(1)	2.16	1.13
incline (14)*EXP(0)	1.76	1.12
incline (14)*EXP(1)	1.56	1.13
incline (26)*EXP(0)	1.79	1.12
incline (26)*EXP(1)	1.55	1.13

Left Tibialis (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	2.07	1.13
Exp1	1.78	1.14
Task reach	1.82	1.09
Task stat	2.16	1.09
Incline 0	1.11	1.09
Incline14	1.36	1.09
Incline 26	5.14	1.09
Cue no	2.00	1.09
Cue yes	1.96	1.09
Load full	1.98	1.09
Load half	2.02	1.09
Load none	1.94	1.09
incline (0)*EXP(0)	1.23	1.13
incline (0)*EXP(1)	0.93	1.15
incline (14)*EXP(0)	1.41	1.13
incline (14)*EXP(1)	1.23	1.15
incline (26)*EXP(0)	5.10	1.13
incline (26)*EXP(1)	4.93	1.15
task (reach)*incline(0)	1.13	1.09
task (reach)*incline(14)	1.34	1.09
task (reach)*incline(26)	3.98	1.09
task (stationary)*incline(0)	1.10	1.09
task (stationary)*incline(14)	1.39	1.10
task (stationary)*incline(26)	6.64	1.10

Right Tibialis (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	2.42	1.13
Exp1	2.10	1.15
Task reach	2.08	1.10
Task stat	2.51	1.10
Incline 0	1.20	1.10
Incline14	1.59	1.10
Incline 26	6.29	1.10
Cue no	2.29	1.10
Cue yes	2.28	1.10
Load full	2.26	1.10
Load half	2.32	1.10
Load none	2.27	1.10
task (reach)*incline(0)	1.21	1.11
task (reach)*incline(14)	1.48	1.11
task (reach)*incline(26)	5.03	1.11
task (stationary)*incline(0)	1.18	1.11
task (stationary)*incline(14)	1.70	1.11
task (stationary)*incline(26)	7.87	1.11

Left Quadricep (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.79	1.16
Exp1	1.56	1.17
Task reach	1.64	1.14
Task stat	1.71	1.14
Incline 0	1.37	1.14
Incline14	1.74	1.14
Incline 26	1.96	1.14
Cue no	1.67	1.14
Cue yes	1.67	1.14
Load full	1.73	1.09
Load half	1.78	1.09
Load none	1.51	1.37

Right Quadricep (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	2.07	1.29
Exp1	1.70	1.32
Task reach	1.73	1.27
Task stat	1.86	1.27
Incline 0	1.44	1.27
Incline14	1.90	1.27
Incline 26	2.10	1.27
Cue no	1.80	1.27
Cue yes	1.78	1.27
Load full	1.82	1.24
Load half	1.98	1.24
Load none	1.60	1.49

Left Hamstring (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.47	1.12
Exp1	1.40	1.13
Task reach	1.51	1.09
Task stat	1.36	1.09
Incline 0	1.37	1.09
Incline14	1.39	1.09
Incline 26	1.53	1.09
Cue no	1.44	1.09
Cue yes	1.42	1.09
Load full	1.43	1.09
Load half	1.45	1.09
Load none	1.41	1.09
incline (0)*EXP(0)	1.41	1.12
incline (0)*EXP(1)	1.32	1.14
incline (14)*EXP(0)	1.36	1.12
incline (14)*EXP(1)	1.43	1.14
incline (26)*EXP(0)	1.64	1.12
incline (26)*EXP(1)	1.44	1.14

Right Hamstring (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.47	1.11
Exp1	1.40	1.12
Task reach	1.54	1.08
Task stat	1.41	1.08
Incline 0	1.28	1.08
Incline14	1.38	1.08
Incline 26	1.81	1.08
Cue no	1.46	1.08
Cue yes	1.49	1.08
Load full	1.50	1.08
Load half	1.46	1.08
Load none	1.45	1.08
incline (0)*EXP(0)	1.23	1.12
incline (0)*EXP(1)	1.26	1.12
incline (14)*EXP(0)	1.35	1.12
incline (14)*EXP(1)	1.35	1.12
incline (26)*EXP(0)	1.91	1.12
incline (26)*EXP(1)	1.60	1.12

Sway Area (cm^2)	Geometric Mean	Geometric Std. Error
Exp0	6.62	1.07
Exp1	7.11	1.07
Task reach	16.53	1.05
Task stat	2.65	1.05
Incline 0	5.76	1.05
Incline14	6.65	1.05
Incline 26	7.58	1.05
Cue no	6.82	1.05
Cue yes	6.43	1.05
Load full	6.62	1.05
Load half	6.64	1.05
Load none	6.61	1.05
task (reach)*EXP(0)	16.73	1.07
task (reach)*EXP(1)	17.60	1.07
task (stationary)*EXP(0)	2.62	1.07
task (stationary)*EXP(1)	2.87	1.07
task (reach)*incline(0)	16.92	1.06
task (reach)*incline(14)	16.79	1.06
task (reach)*incline(26)	15.89	1.06
task (stationary)*incline(0)	1.96	1.06
task (stationary)*incline(14)	2.63	1.06
task (stationary)*incline(26)	3.62	1.06

Sway Length (cm)	Geometric Mean	Geometric Std. Error
Exp0	66.94	1.03
Exp1	75.91	1.03
Task reach	108.92	1.02
Task stat	45.97	1.02
Incline 0	60.15	1.02
Incline14	70.08	1.02
Incline 26	84.03	1.02
Cue no	72.61	1.02
Cue yes	68.95	1.02
Load full	71.64	1.02
Load half	70.77	1.02
Load none	69.88	1.02
task (reach)*incline(0)	100.06	1.03
task (reach)*incline(14)	110.17	1.03
task (reach)*incline(26)	117.20	1.03
task (stationary)*incline(0)	36.16	1.03
task (stationary)*incline(14)	44.59	1.03
task (stationary)*incline(26)	60.26	1.03
task (reach)*EXP(0)	105.70	1.03
task (reach)*EXP(1)	113.24	1.04
task (stationary)*EXP(0)	42.39	1.03
task (stationary)*EXP(1)	50.89	1.04

Medio/Lateral Excursion (X, cm)	**Geometric Mean**	**Geometric Std. Error**
Exp0	2.32	1.04
Exp1	2.57	1.05
Task reach	3.68	1.04
Task stat	1.62	1.04
Incline 0	2.06	1.04
Incline14	2.45	1.04
Incline 26	2.86	1.04
Cue no	2.45	1.04
Cue yes	2.42	1.04
Load full	2.44	1.04
Load half	2.41	1.04
Load none	2.46	1.04
task (reach)*incline(0)	3.42	1.04
task (reach)*incline(14)	3.66	1.04
task (reach)*incline(26)	3.97	1.04
task (stationary)*incline(0)	1.24	1.04
task (stationary)*incline(14)	1.64	1.04
task (stationary)*incline(26)	2.07	1.04
task (reach)*cue(no)	3.73	1.04
task (reach)*cue(yes)	3.62	1.04
task (stationary)*cue(no)	1.61	1.04
task (stationary)*cue(yes)	1.62	1.04

Anterior/Posterior Excursion (Y, cm)	**Geometric Mean**	**Geometric Std. Error**
Exp0	4.73	1.03
Exp1	4.77	1.04
Task reach	8.02	1.02
Task stat	2.81	1.03
Incline 0	4.72	1.03
Incline14	4.70	1.03
Incline 26	4.83	4.83
Cue no	4.84	1.02
Cue yes	4.66	1.03
Load full	4.79	1.03
Load half	4.78	1.03
Load none	4.69	1.03
task (reach)*incline(0)	8.50	1.03
task (reach)*incline(14)	8.14	1.03
task (reach)*incline(26)	7.44	1.03
task (stationary)*incline(0)	2.62	1.03
task (stationary)*incline(14)	2.72	1.03
task (stationary)*incline(26)	3.14	1.03
task (reach)*EXP(0)	8.12	1.03
task (reach)*EXP(1)	7.88	1.04
task (stationary)*EXP(0)	2.75	1.03
task (stationary)*EXP(1)	2.89	1.04

Table S-12. P-values for Significant Effect of EMG on Postural Sway from 25%ile Structural Models with Experience/Inexperienced, Months of job experience and Hours of Work Activity (parenthesis indicate the Number of models the variable was significant in).

Experimental Condition or Independent Variable	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Left Gastrocnemius		**0.0028-0.013** (2)		
Left Hamstring	**0.0013** (1)			
Right Gastrocnemius	**0.019** (1)			
Right Quadricep				**0.0012** (1)

Table S-13. Range of P-values for testing the effects of experience, load, task, inclination and visual cue in the Structural Equation Model for EMG at the 5th percentile and Postural Sway Outcomes.

Experimental Condition or Independent Variable	LG	LH	LQ	LT	RG	RH	RQ	RT	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Range of R-square values	0.023-0.032	0.038	0.059-0.065	0.28	0.017-0.03	0.051-0.068	0.05-0.055	0.298	0.75	0.661-0.669	0.538-0.539	0.728-0.743
Work Experience Variables:												
Experienced vs. Inexperienced	0.22	0.28	0.33	**0.0007**	0.2	0.99	0.07	**0.006**	0.99	0.98	0.99	0.99
Months of Work Experience	0.91	**0.0004**	0.71	0.99	**0.0001**	0.94	**0.003**	0.19	0.95	0.99	0.99	**0.0001**
Hours of Work Activity	0.93	**0.0002**	0.99	0.99	**0.001**	0.72	**0.0001**	0.007	0.99	0.26	0.22	0.99
Load Variables:												
Fatiguing Task Performed (Full vs. Half vs. None)	0.12-0.2	0.09-0.5	0.35-0.95	0.94-0.95	0.13-0.96	0.08-0.94	0.08-0.97	0.95-0.96	0.77-0.91	0.74-0.92	0.79-0.88	0.093-0.81
Experimental Conditions:												
Task (Reach vs. Stationary)	0.51-0.54	0.34-0.93	0.16-0.99	0.18-0.99	0.17-0.68	0.39-0.73	0.4-0.99	0.39-0.73	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Inclination (0 vs. 14 vs. 26 degrees)	**0.009-0.01**	**0.008-0.01**	**0.0001**	**0.0001**	**0.001-0.01**	**0.0001**	**0.0001**	**0.001-0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Visual Cue	0.91-0.94	0.33-0.5	0.46-0.83	0.46-0.85	0.44-0.84	0.33-0.77	0.37-0.5	0.63-0.79	0.09-0.1	**0.02-0.055**	0.8-0.83	0.11

Experimental Condition or Independent Variable	LG	LH	LQ	LT	RG	RH	RQ	RT	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Interactions of Experience Variables												
Experience*Incline			0.009		0.02	0.0001						
Experience * Task									0.0038	0.0006		0.001
Months of work experience * Gastrocnemius muscle activity				0.02		0.02						
Months of work experience* Hamstring muscle activity		0.0001					0.003					
Hours of work activity * Hamstring muscle activity						0.0001						
Hours of work activity * Task										0.01		0.004
Hours of work activity * Incline	0.003					0.0001						
Interactions of Experimental Conditions												
Task * Cue											0.02-0.03	
Task * Incline			0.0001	0.0001	0.0001		0.05	0.0001	0.0001	0.0001	0.0001	0.0001

Table S-14. Least Square Means for EMG and postural sway variables for the median of the three SEM's at the 5%ile

Left Gastrocnemius (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.29	1.12
Exp1	1.43	1.13
Task reach	1.27	1.05
Task stat	1.30	1.05
Incline 0	1.40	1.05
Incline14	1.20	1.05
Incline 26	1.27	1.05
Cue no	1.27	1.05
Cue yes	1.30	1.05
Load full	1.31	1.05
Load half	1.29	1.05
Load none	1.26	1.05

Right Gastrocnemius (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.21	1.07
Exp1	1.17	1.07
Task reach	1.22	1.05
Task stat	1.22	1.05
Incline 0	1.29	1.05
Incline14	1.15	1.05
Incline 26	1.22	1.05
Cue no	1.22	1.05
Cue yes	1.22	1.05
Load full	1.23	1.05
Load half	1.21	1.05
Load none	1.22	1.05
incline (0)*EXP(0)	1.24	1.07
incline (0)*EXP(1)	1.25	1.08
incline (14)*EXP(0)	1.15	1.07
incline (14)*EXP(1)	1.11	1.08
incline (26)*EXP(0)	1.24	1.07
incline (26)*EXP(1)	1.14	1.08

Left Tibialis (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.30	1.07
Exp1	1.30	1.07
Task reach	1.15	1.05
Task stat	1.47	1.05
Incline 0	1.01	1.05
Incline14	1.11	1.05
Incline 26	1.96	1.05
Cue no	1.30	1.05
Cue yes	1.30	1.05
Load full	1.32	1.05
Load half	1.32	1.05
Load none	1.27	1.05
task (reach)*incline(0)	1.03	1.06
task (reach)*incline(14)	1.08	1.06
task (reach)*incline(26)	1.38	1.06
task (stationary)*incline(0)	1.00	1.06
task (stationary)*incline(14)	1.13	1.06
task (stationary)*incline(26)	2.80	1.06

Right Tibialis (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.36	1.08
Exp1	1.27	1.09
Task reach	1.13	1.07
Task stat	1.49	1.07
Incline 0	0.99	1.07
Incline14	1.12	1.07
Incline 26	1.97	1.07
Cue no	1.29	1.07
Cue yes	1.31	1.07
Load full	1.29	1.07
Load half	1.30	1.07
Load none	1.30	1.07
task (reach)*incline(0)	0.99	1.07
task (reach)*incline(14)	1.07	1.07
task (reach)*incline(26)	1.36	1.07
task (stationary)*incline(0)	0.99	1.07
task (stationary)*incline(14)	1.17	1.07
task (stationary)*incline(26)	2.86	1.07

Left Quadricep (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.30	1.09
Exp1	1.25	1.10
Task reach	1.34	1.15
Task stat	1.45	1.15
Incline 0	1.25	1.15
Incline14	1.43	1.15
Incline 26	1.53	1.15
Cue no	1.39	1.15
Cue yes	1.40	1.15
Load full	1.36	1.15
Load half	1.39	1.15
Load none	1.43	1.15
task (reach)*incline(0)	1.25	1.15
task (reach)*incline(14)	1.42	1.15
task (reach)*incline(26)	1.42	1.15
task (stationary)*incline(0)	1.28	1.15
task (stationary)*incline(14)	1.48	1.15
task (stationary)*incline(26)	1.69	1.15
incline (0)*EXP(0)	1.16	1.09
incline (0)*EXP(1)	1.12	1.10
incline (14)*EXP(0)	1.36	1.09
incline (14)*EXP(1)	1.25	1.10
incline (26)*EXP(0)	1.40	1.09
incline (26)*EXP(1)	1.38	1.10

Right Quadricep (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.30	1.19
Exp1	1.30	1.23
Task reach	1.11	1.12
Task stat	1.30	1.12
Incline 0	1.07	1.12
Incline14	1.29	1.12
Incline 26	1.26	1.12
Cue no	1.21	1.12
Cue yes	1.20	1.12
Load full	1.33	1.08
Load half	1.39	1.08
Load none	0.94	1.30
task (reach)*incline(0)	1.04	1.12
task (reach)*incline(14)	1.20	1.12
task (reach)*incline(26)	1.11	1.12
task (stationary)*incline(0)	1.09	1.12
task (stationary)*incline(14)	1.39	1.12
task (stationary)*incline(26)	1.44	1.12

Left Hamstring (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.18	1.07
Exp1	1.14	1.07
Task reach	1.19	1.12
Task stat	1.14	1.12
Incline 0	1.11	1.12
Incline14	1.15	1.12
Incline 26	1.23	1.12
Cue no	1.16	1.12
Cue yes	1.16	1.12
Load full	1.15	1.12
Load half	1.17	1.12
Load none	1.17	1.12

Right Hamstring (Ln % MVC)	Geometric Mean	Geometric Std. Error
Exp0	1.21	1.06
Exp1	1.16	1.07
Task reach	1.24	1.11
Task stat	1.19	1.11
Incline 0	1.13	1.11
Incline14	1.13	1.11
Incline 26	1.40	1.11
Cue no	1.20	1.11
Cue yes	1.23	1.11
Load full	1.22	1.11
Load half	1.22	1.11
Load none	1.21	1.11
incline (0)*EXP(0)	1.10	1.07
incline (0)*EXP(1)	1.11	1.07
incline (14)*EXP(0)	1.10	1.07
incline (14)*EXP(1)	1.12	1.07
incline (26)*EXP(0)	1.48	1.06
incline (26)*EXP(1)	1.24	1.07

Sway Area (cm^2)	Geometric Mean	Geometric Std. Error
Exp0	6.36	1.06
Exp1	6.90	1.07
Task reach	16.53	1.05
Task stat	2.65	1.05
Incline 0	5.74	1.05
Incline14	6.65	1.05
Incline 26	7.58	1.05
Cue no	6.83	1.05
Cue yes	6.42	1.05
Load full	6.62	1.05
Load half	6.64	1.05
Load none	6.61	1.05
task (reach)*EXP(0)	16.16	1.07
task (reach)*EXP(1)	16.90	1.07
task (stationary)*EXP(0)	2.51	1.07
task (stationary)*EXP(1)	2.82	1.07
task (reach)*incline(0)	16.86	1.05
task (reach)*incline(14)	16.77	1.06
task (reach)*incline(26)	15.87	1.06
task (stationary)*incline(0)	1.96	1.05
task (stationary)*incline(14)	2.63	1.05
task (stationary)*incline(26)	3.62	1.06

Sway Length (cm)	Geometric Mean	Geometric Std. Error
Exp0	66.98	1.03
Exp1	74.35	1.03
Task reach	108.82	1.03
Task stat	45.90	1.02
Incline 0	60.16	1.03
Incline14	69.76	1.03
Incline 26	83.80	1.03
Cue no	72.51	1.03
Cue yes	68.70	1.03
Load full	71.49	1.03
Load half	70.55	1.03
Load none	69.71	1.03
task (reach)*incline(0)	100.41	1.03
task (reach)*incline(14)	109.63	1.03
task (reach)*incline(26)	116.76	1.03
task (stationary)*incline(0)	36.02	1.03
task (stationary)*incline(14)	44.52	1.03
task (stationary)*incline(26)	60.22	1.03
task (reach)*EXP(0)	105.77	1.03
task (reach)*EXP(1)	111.29	1.04
task (stationary)*EXP(0)	42.41	1.03
task (stationary)*EXP(1)	49.68	1.04

Medio/Lateral Excursion (X, cm)	Geometric Mean	Geometric Std. Error
Exp0	2.26	1.04
Exp1	2.50	1.04
Task reach	3.62	1.04
Task stat	1.59	1.04
Incline 0	2.03	1.04
Incline14	2.42	1.04
Incline 26	2.82	1.04
Cue no	2.41	1.04
Cue yes	2.39	1.04
Load full	2.40	1.04
Load half	2.38	1.04
Load none	2.42	1.04
task (reach)*incline(0)	3.37	1.04
task (reach)*incline(14)	3.60	1.04
task (reach)*incline(26)	3.90	1.04
task (stationary)*incline(0)	1.22	1.04
task (stationary)*incline(14)	1.62	1.04
task (stationary)*incline(26)	2.03	1.04
task (reach)*cue(no)	3.68	1.04
task (reach)*cue(yes)	3.56	1.04
task (stationary)*cue(no)	1.58	1.04
task (stationary)*cue(yes)	1.60	1.04

Anterior/Posterior Excursion (Y, cm)	Geometric Mean	Geometric Std. Error
Exp0	4.96	1.05
Exp1	4.92	1.06
Task reach	8.32	1.05
Task stat	2.93	1.05
Incline 0	4.90	1.05
Incline14	4.89	1.05
Incline 26	5.03	1.05
Cue no	5.04	1.05
Cue yes	4.85	1.05
Load full	4.98	1.05
Load half	4.97	1.05
Load none	4.87	1.05
task (reach)*incline(0)	8.83	1.05
task (reach)*incline(14)	8.46	1.05
task (reach)*incline(26)	7.73	1.05
task (stationary)*incline(0)	2.72	1.05
task (stationary)*incline(14)	2.83	1.05
task (stationary)*incline(26)	3.27	1.05
task (reach)*EXP(0)	8.52	1.05
task (reach)*EXP(1)	8.14	1.06
task (stationary)*EXP(0)	2.89	1.05
task (stationary)*EXP(1)	2.98	1.06

Table S-15. P-values for Significant Effect of EMG on Postural Sway from 5%ile Structural Models with Experience/Inexperienced, Months of job experience and Hours of Work Activity (parenthesis indicate the Number of models the variable was significant in).

Experimental Condition or Independent Variable	Sway Area	Sway Length	Excursion in the X direction	Excursion in the Y direction
Left Gastrocnemius		**0.0009**		
Left Hamstring	**0.006**			
Right Gastrocnemius			**0.0001**	

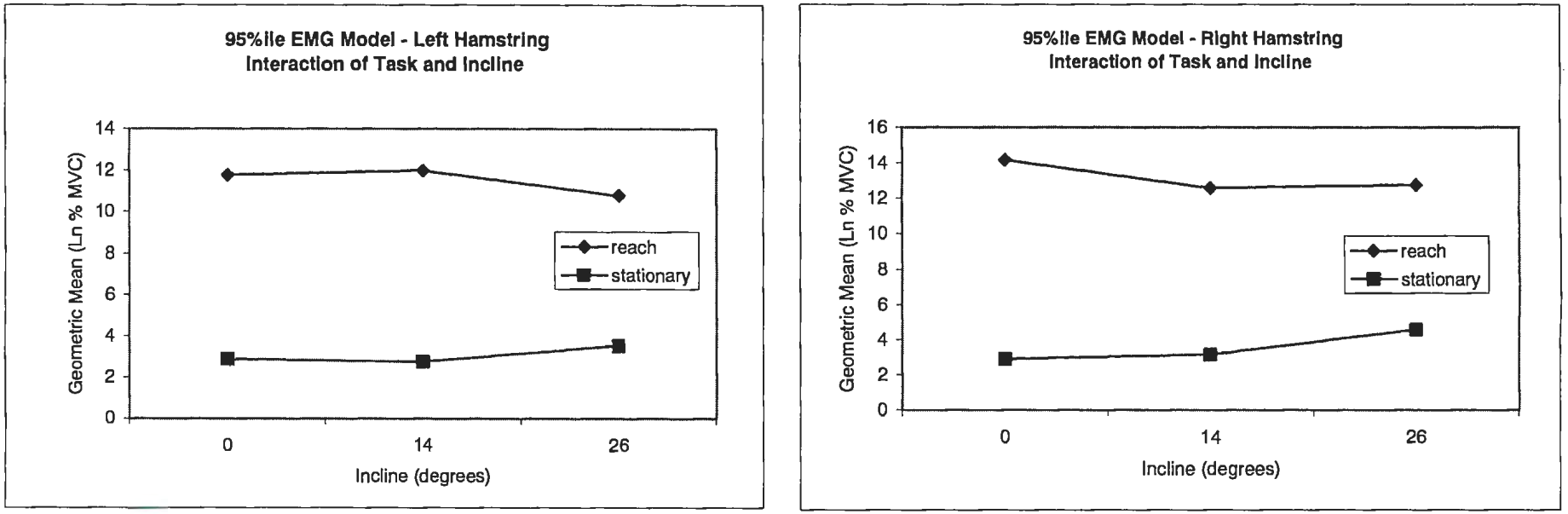
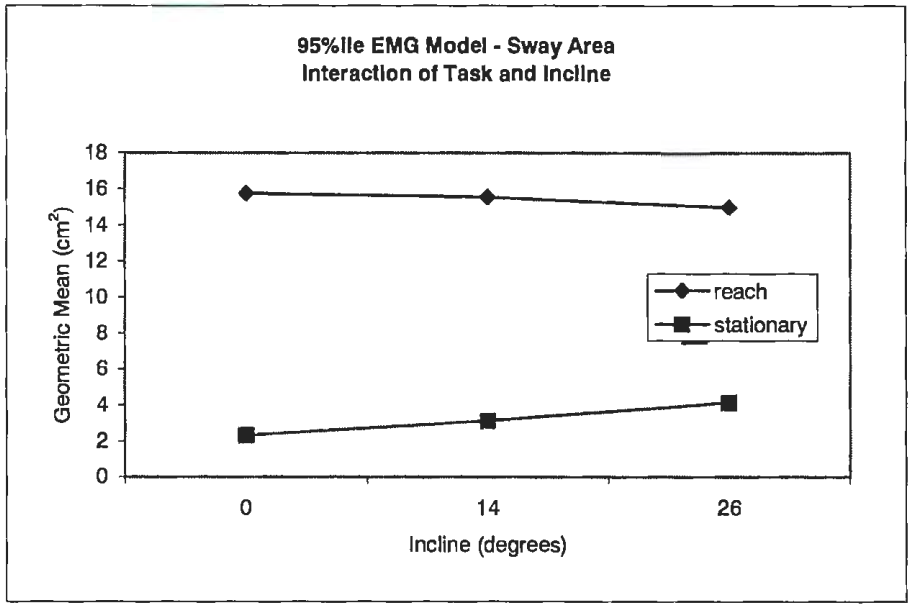
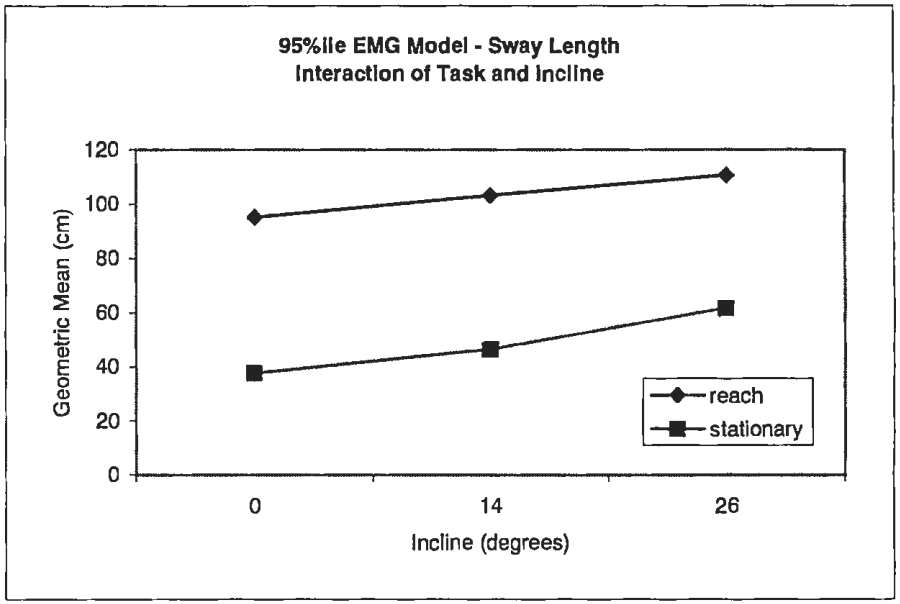


Figure S-1. Interactions for 95%ile EMG Model - Hamstring





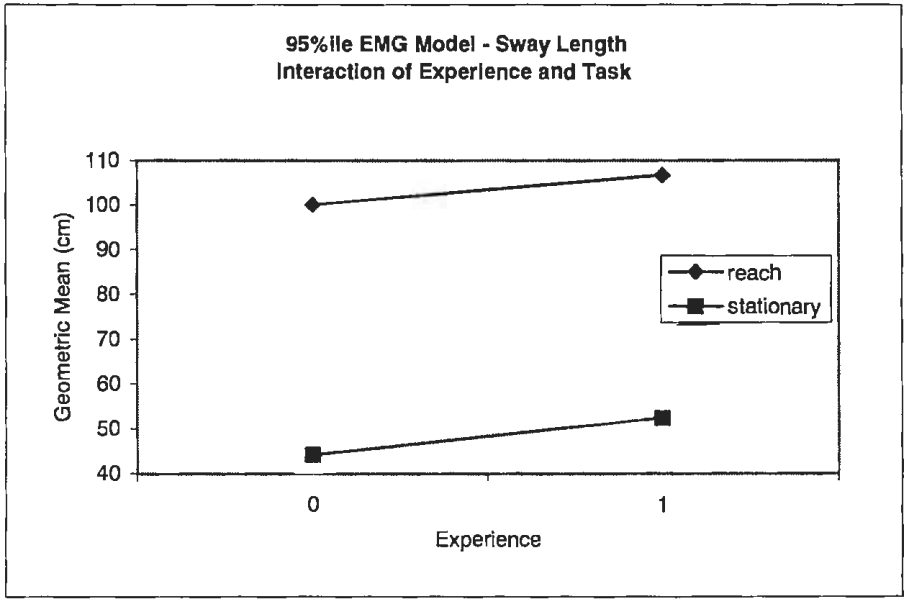
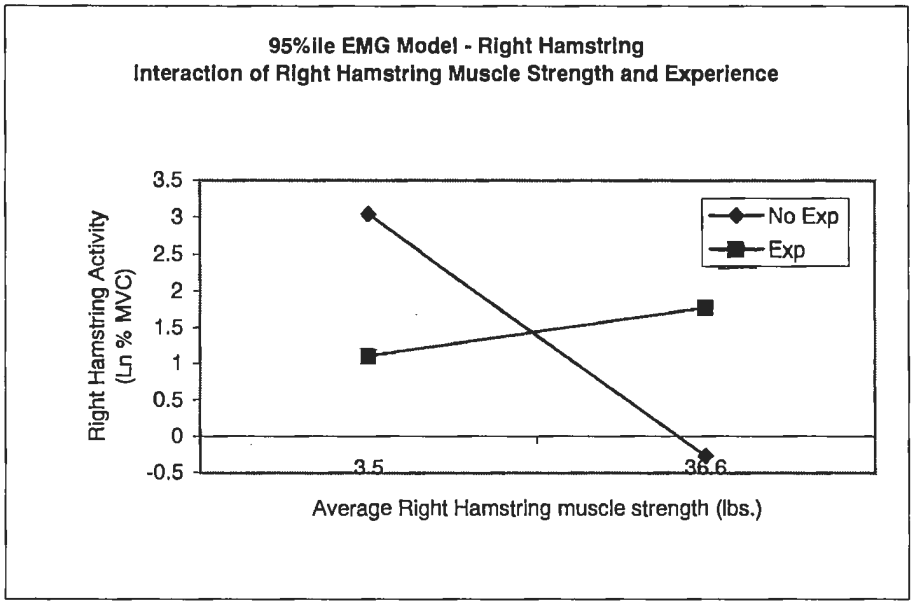


Figure S-2. Interactions for 95%ile EMG Model - Sway Area and Sway Length



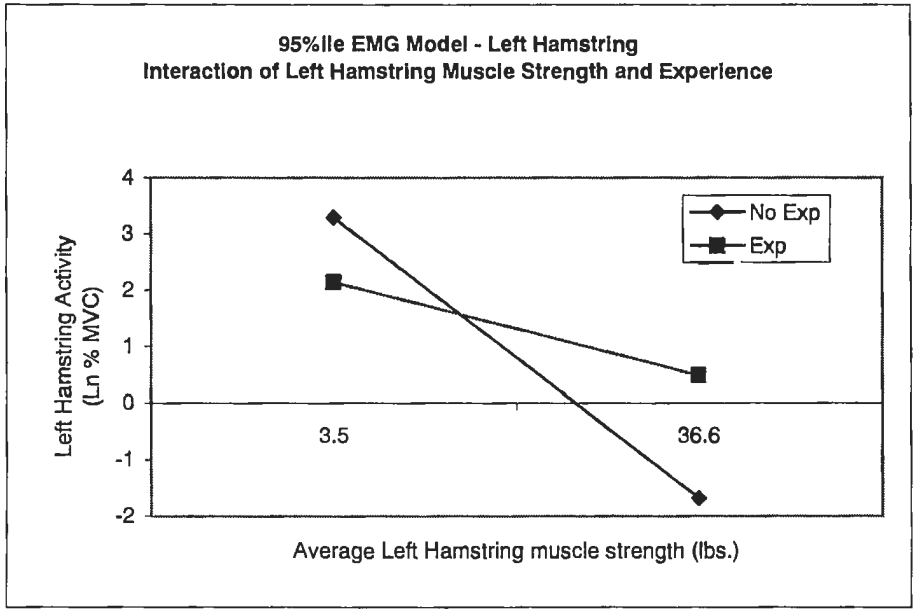
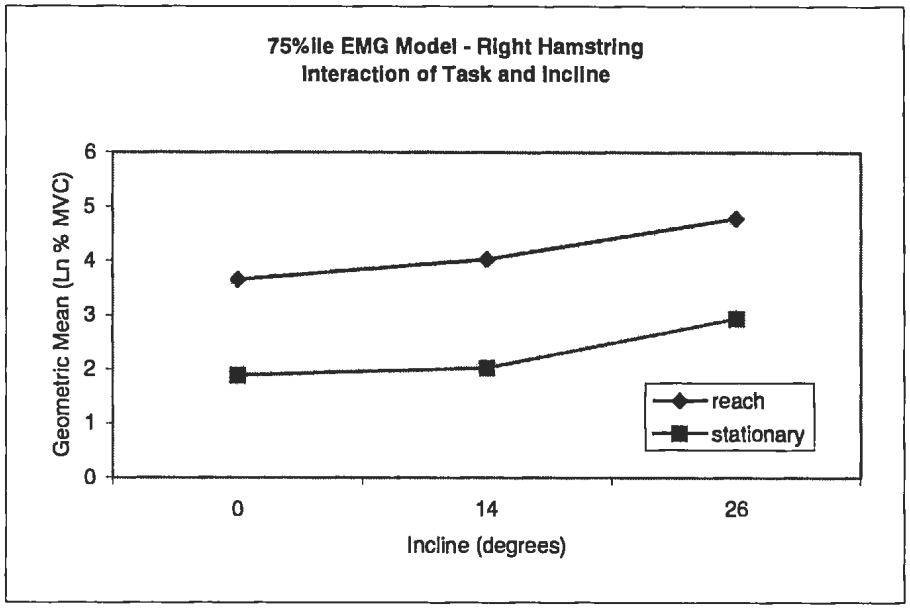
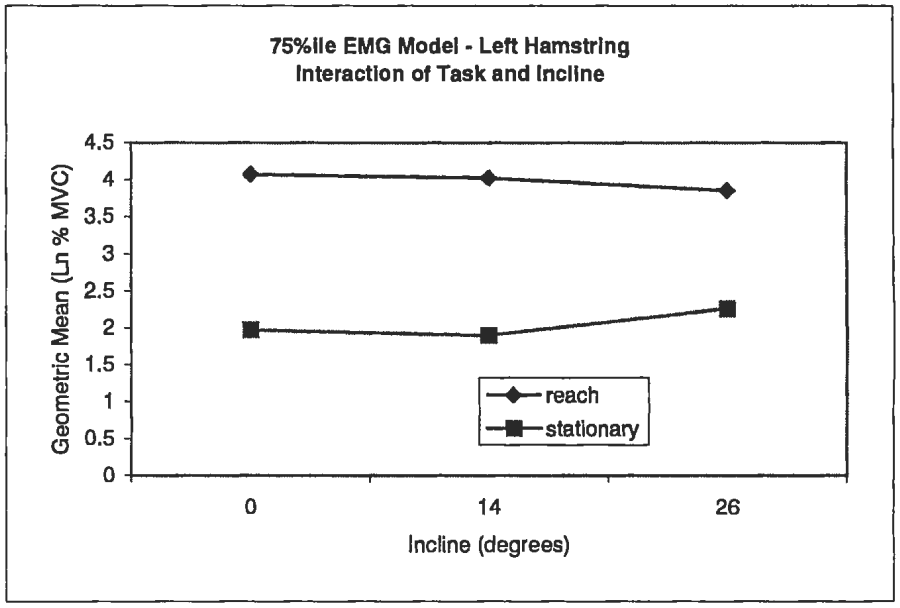
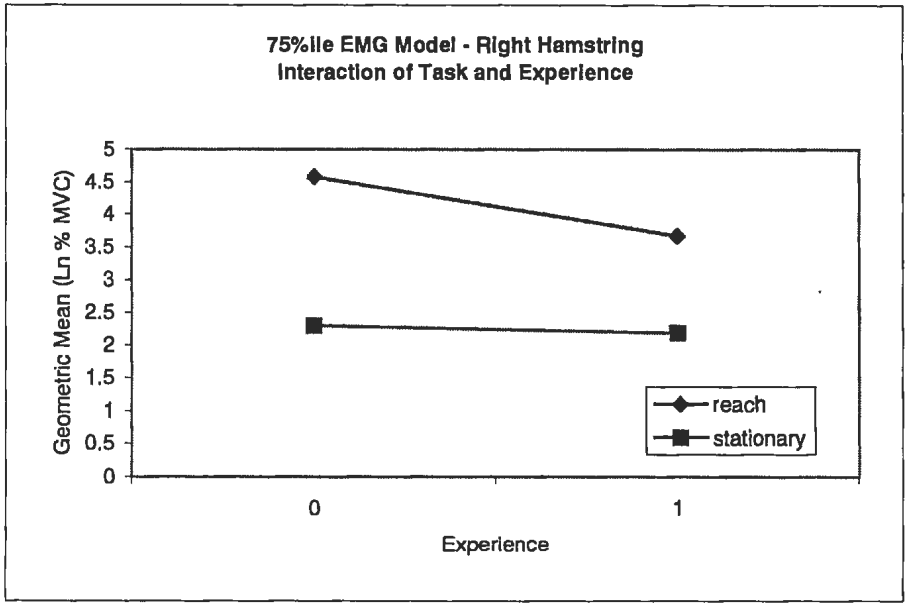


Figure S-3. Interactions for 95%ile EMG Model - Hamstring Muscle Strength







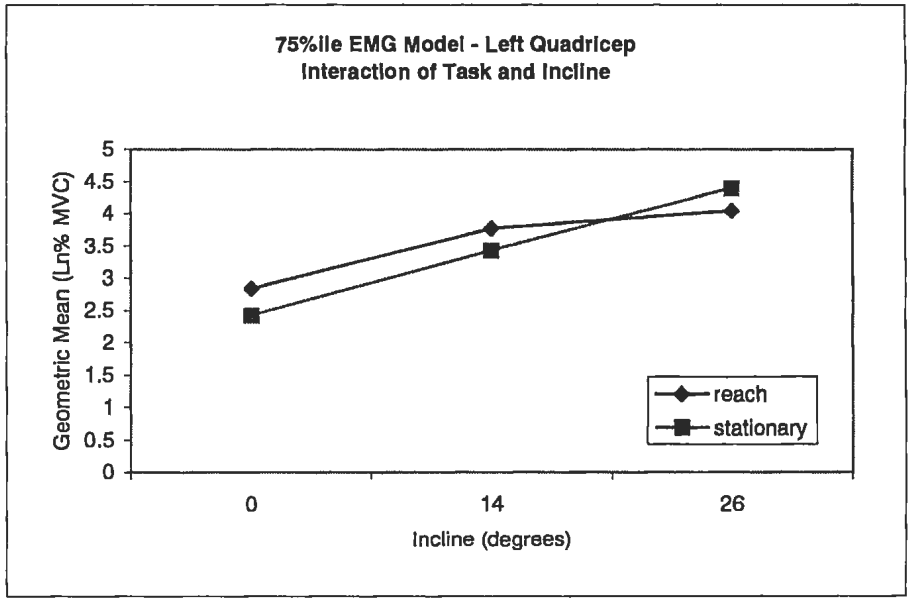
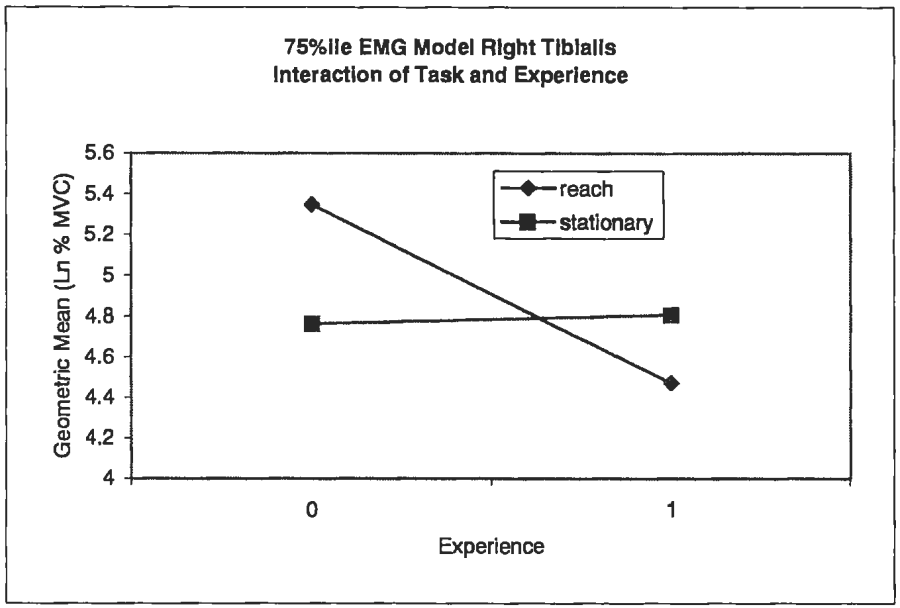
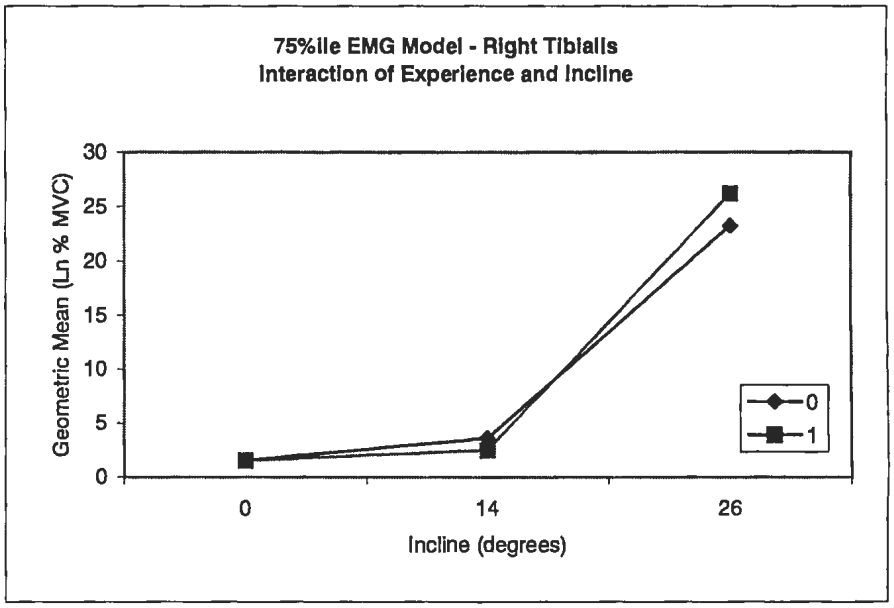
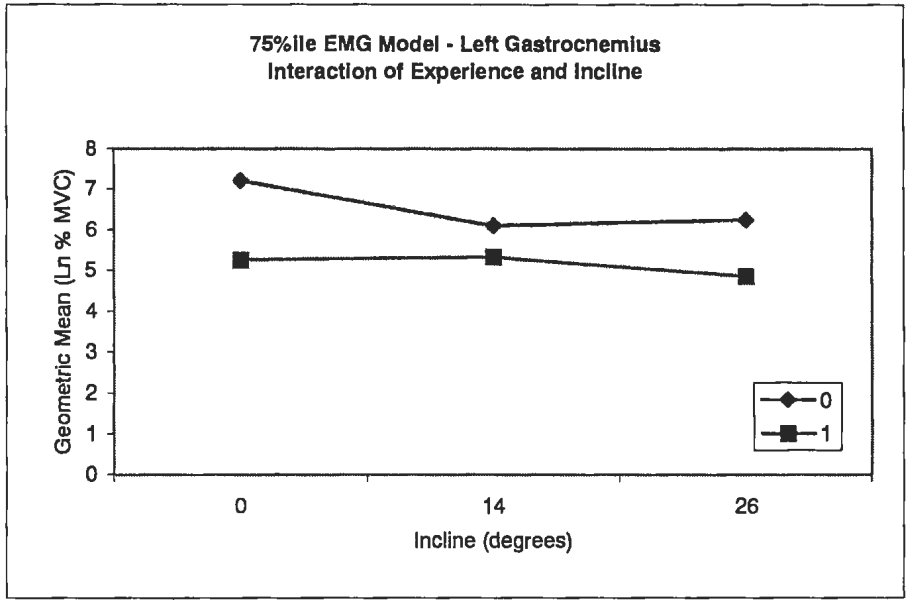


Figure S-4. Interactions for 75%ile EMG Model - Hamstring and Quadricep







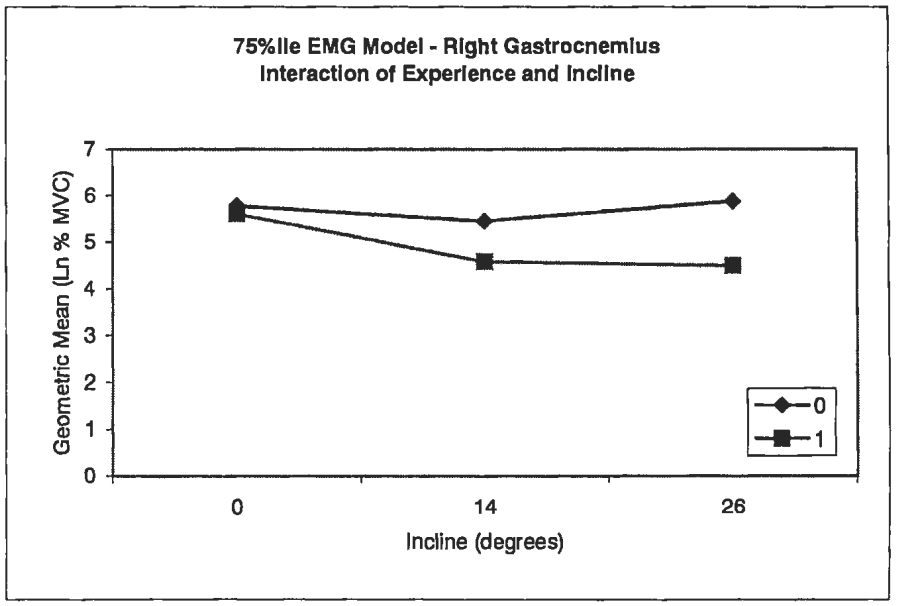
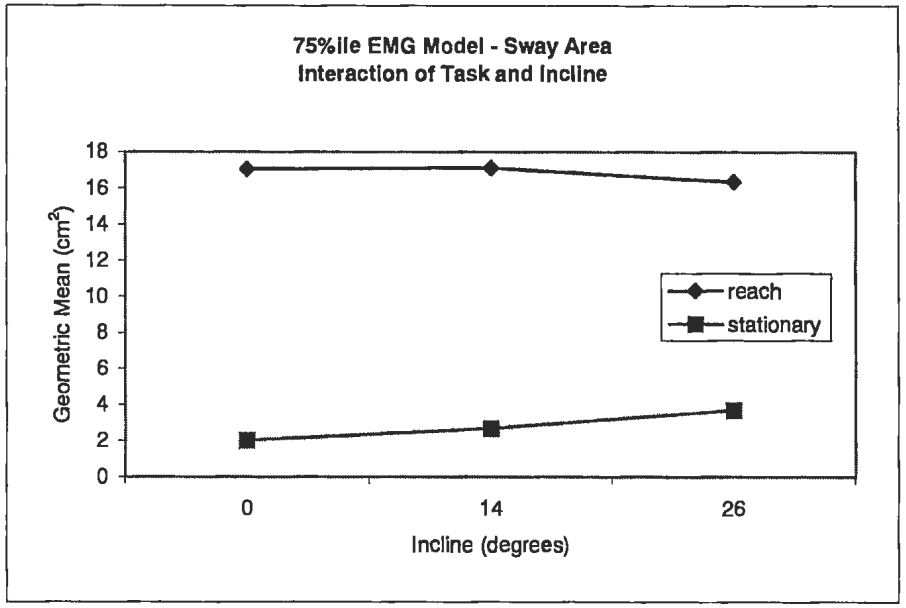
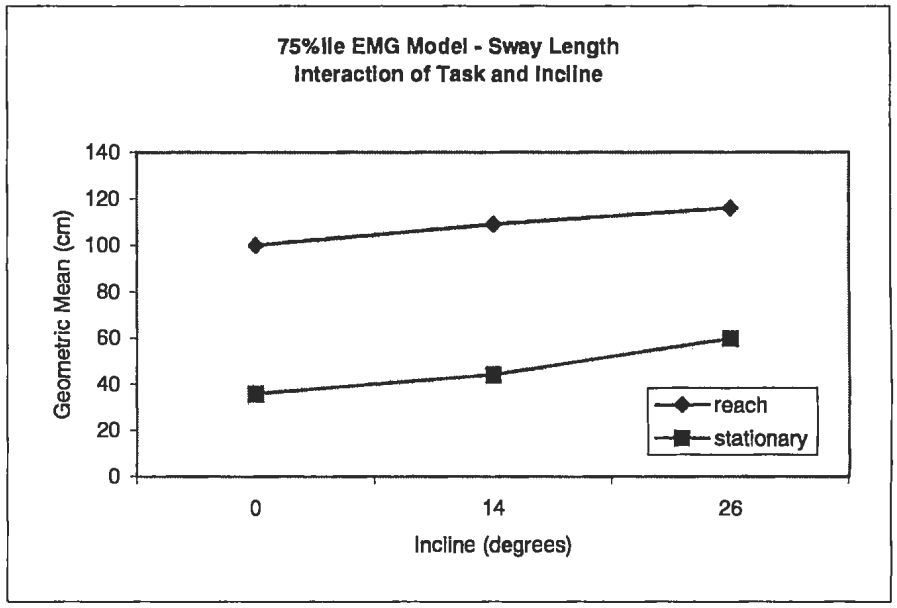
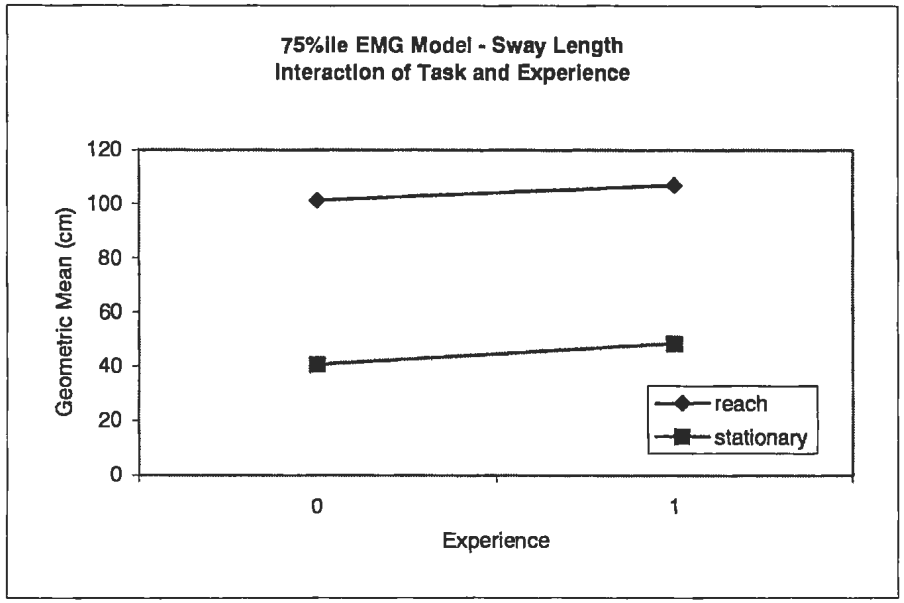


Figure S-5. Interactions for 75%ile EMG Model - Tibialis and Gastrocnemius







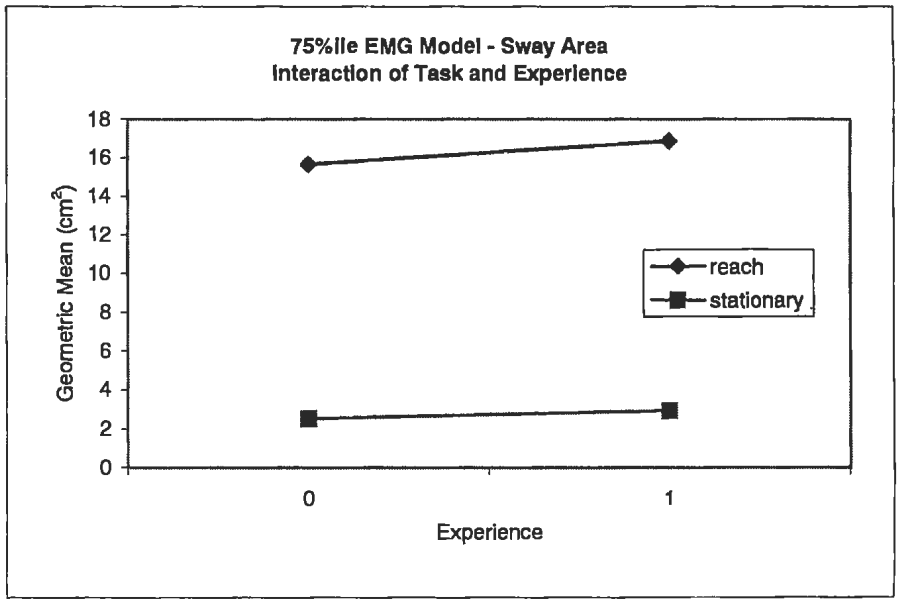
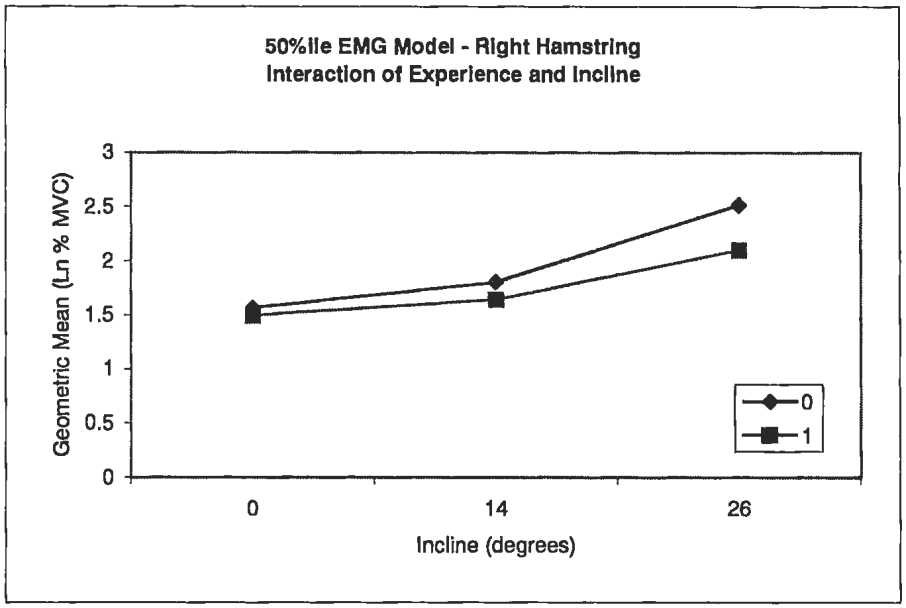
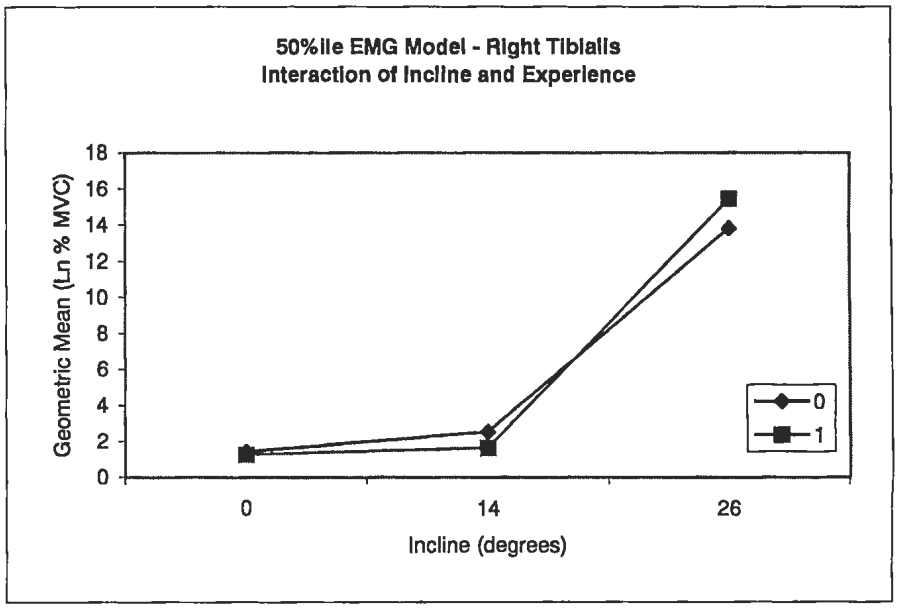


Figure S-6. Interactions for 75%ile EMG Model - Sway Area and Sway Length





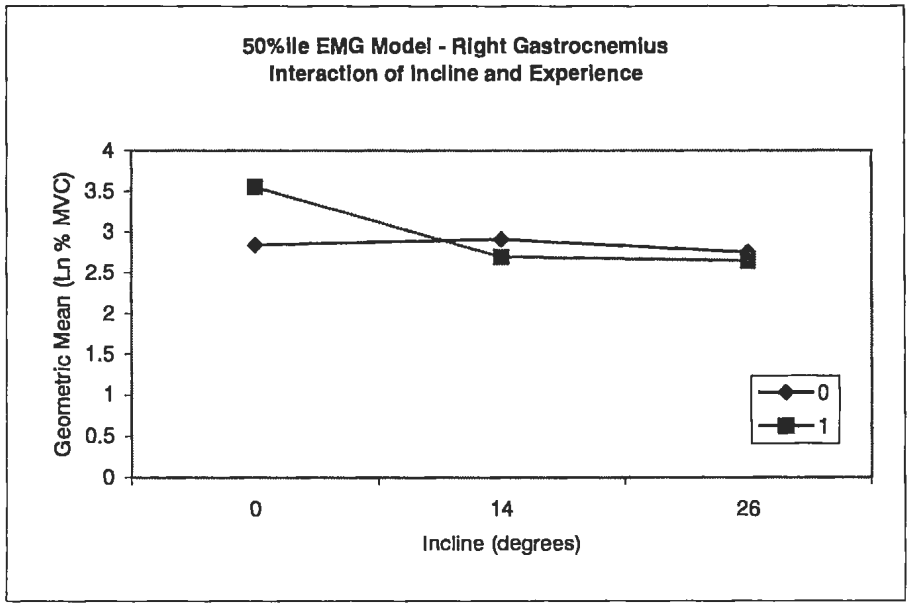
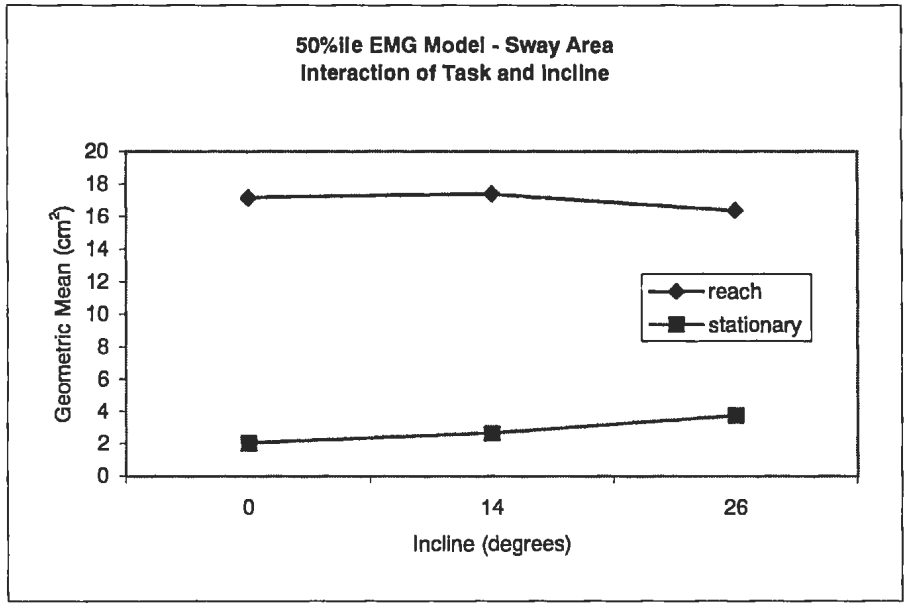
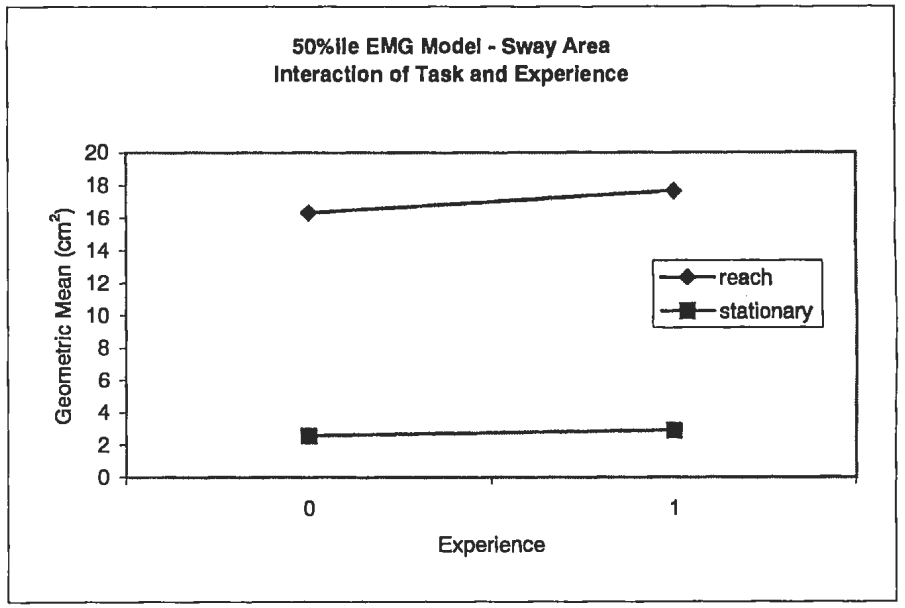
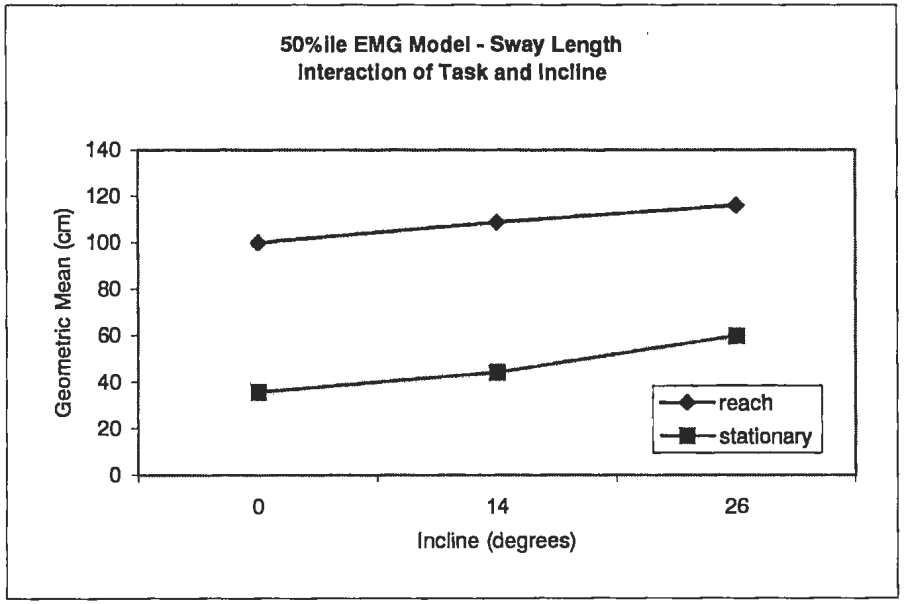


Figure S-7. Interactions for 50%ile EMG Model - Muscle Groups







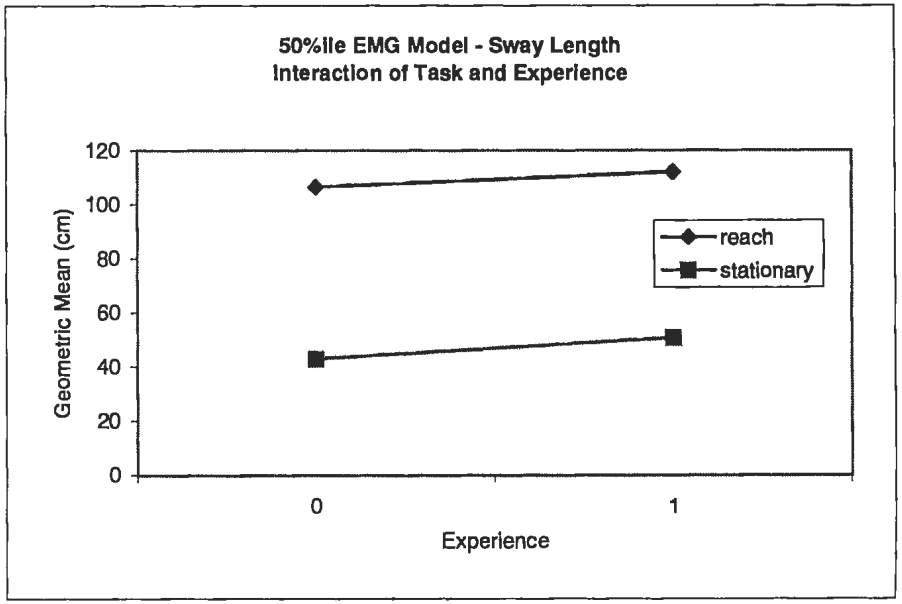
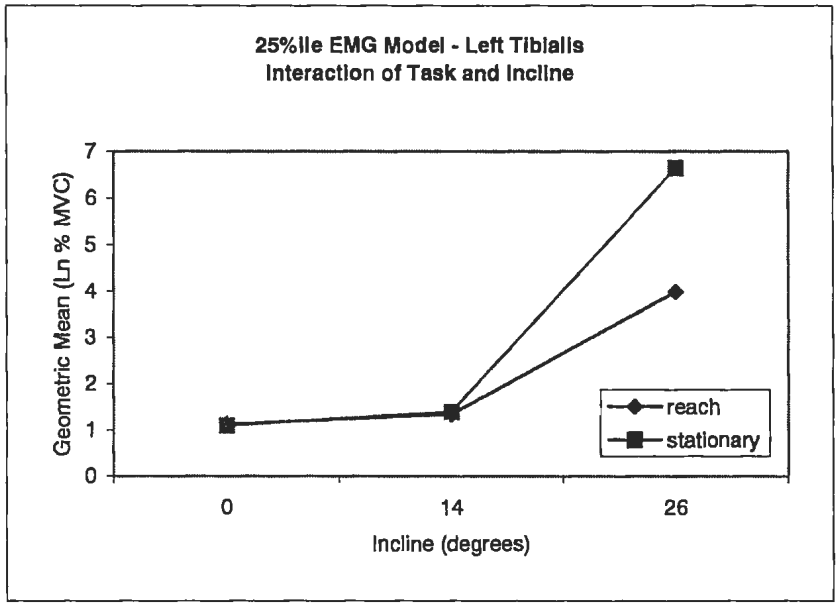
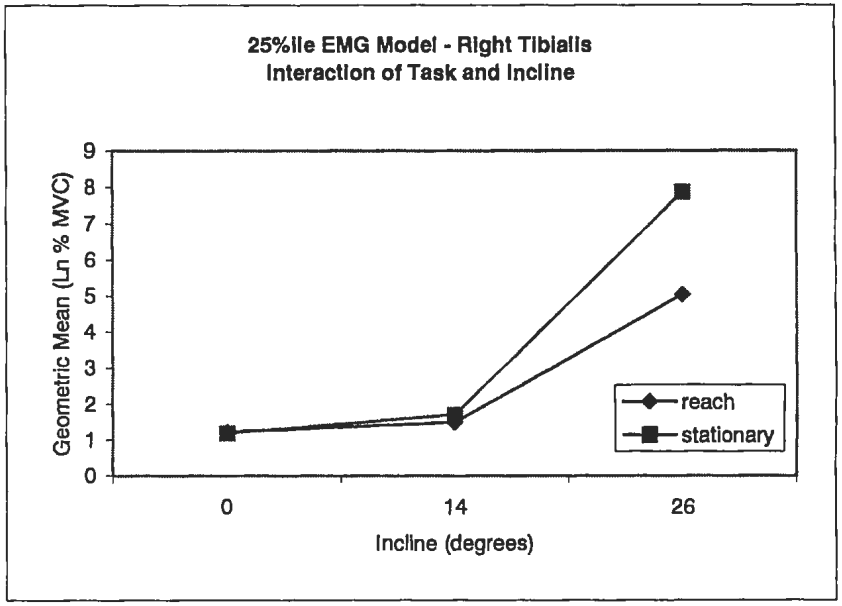


Figure S-8. Interactions for 50%ile EMG Model - Sway Area and Sway Length





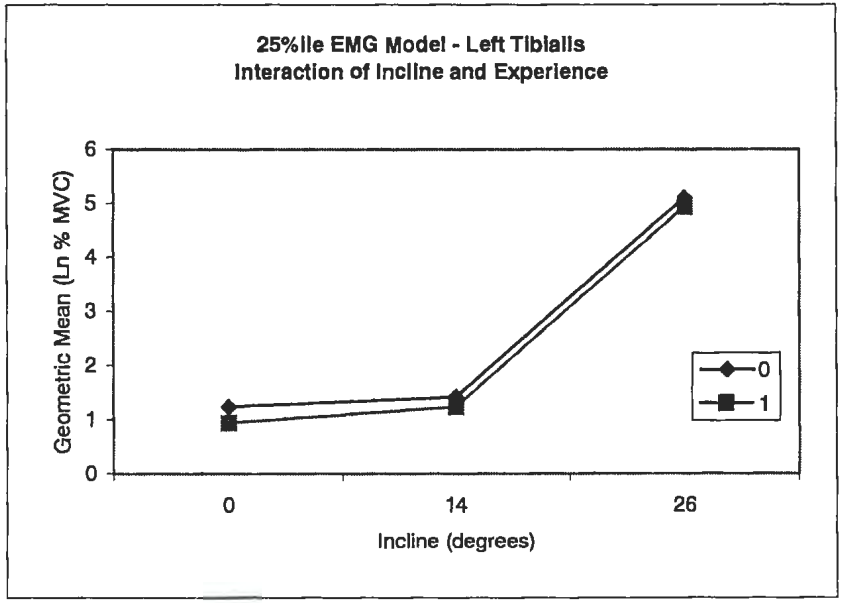
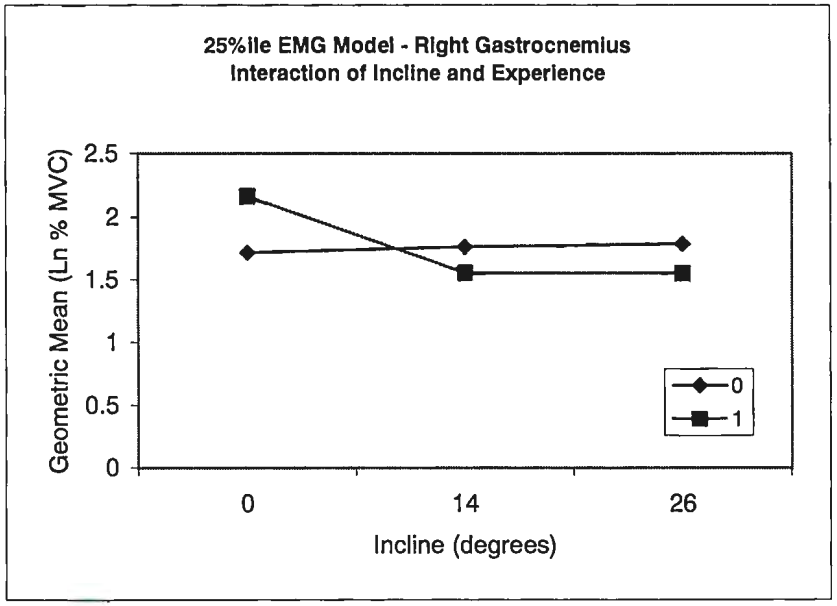


Figure S-9. Interactions for 25%ile EMG Model - Tibialis



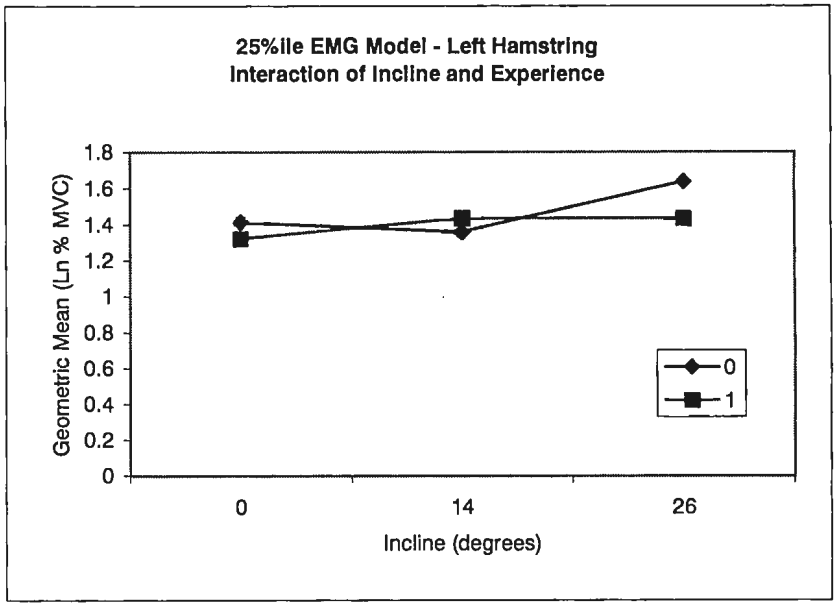
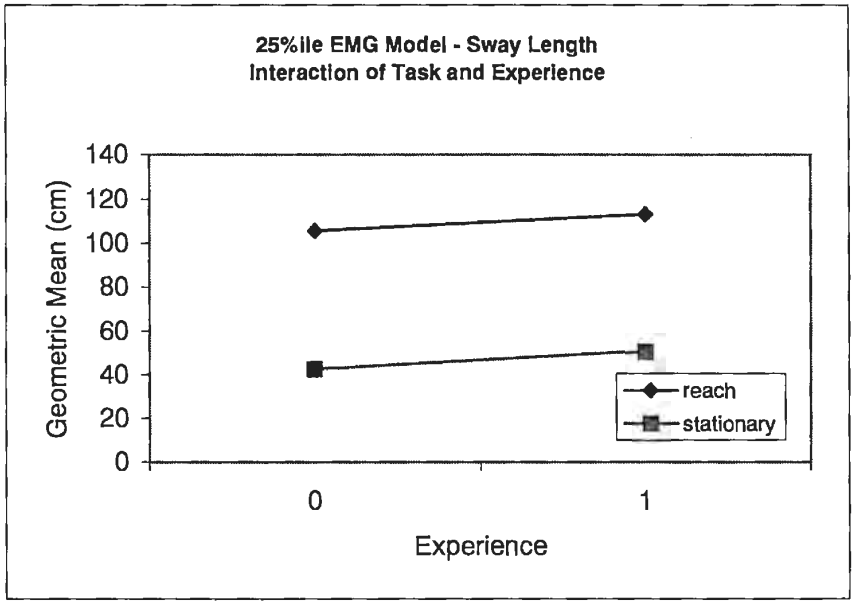
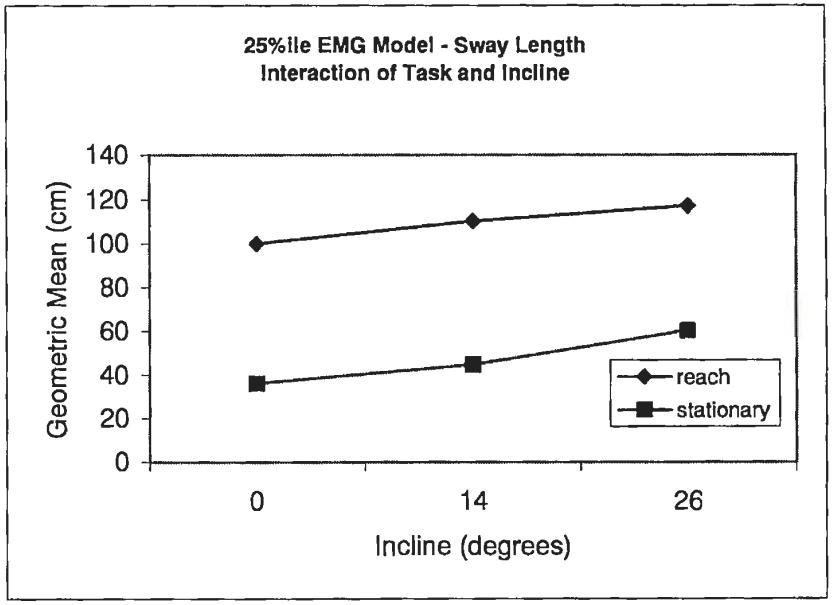
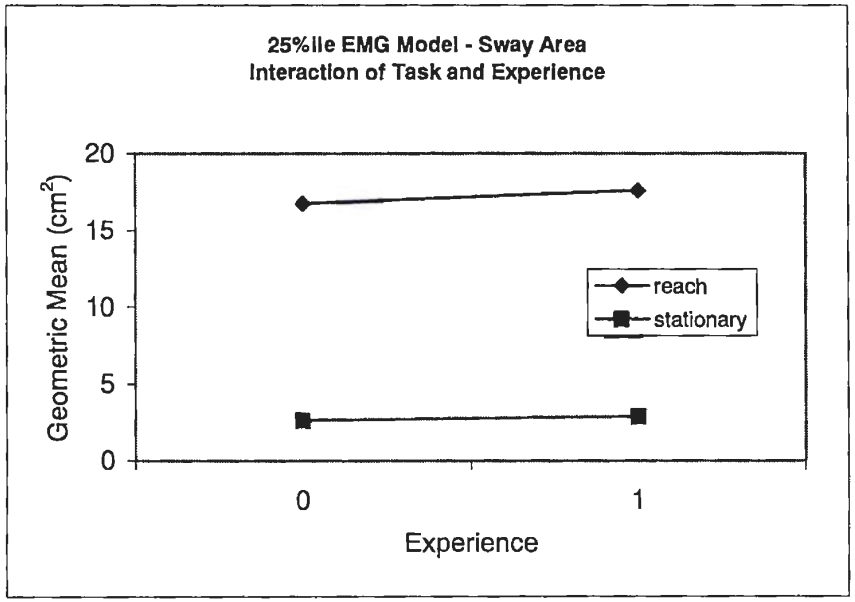


Figure S-10. Interactions for 25%ile EMG Model - Gastrocnemius and Hamstring







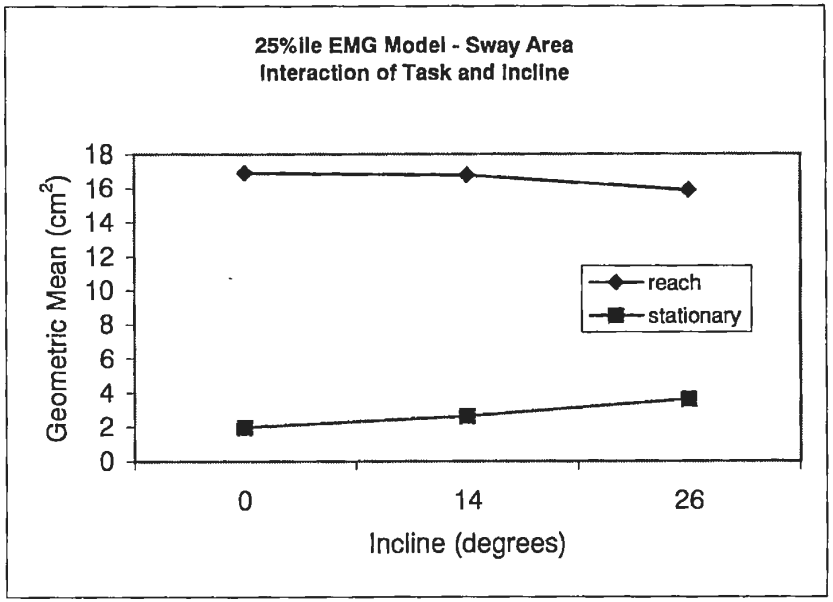
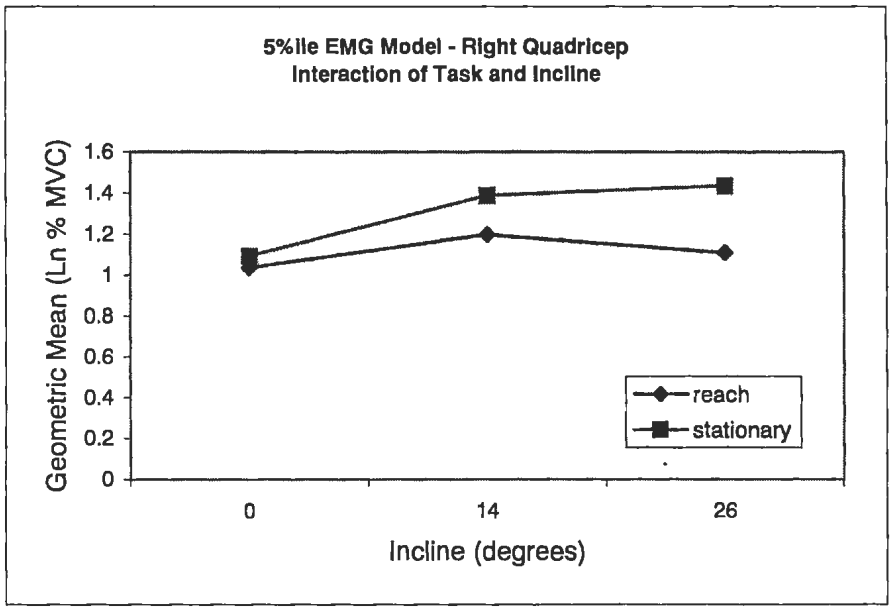
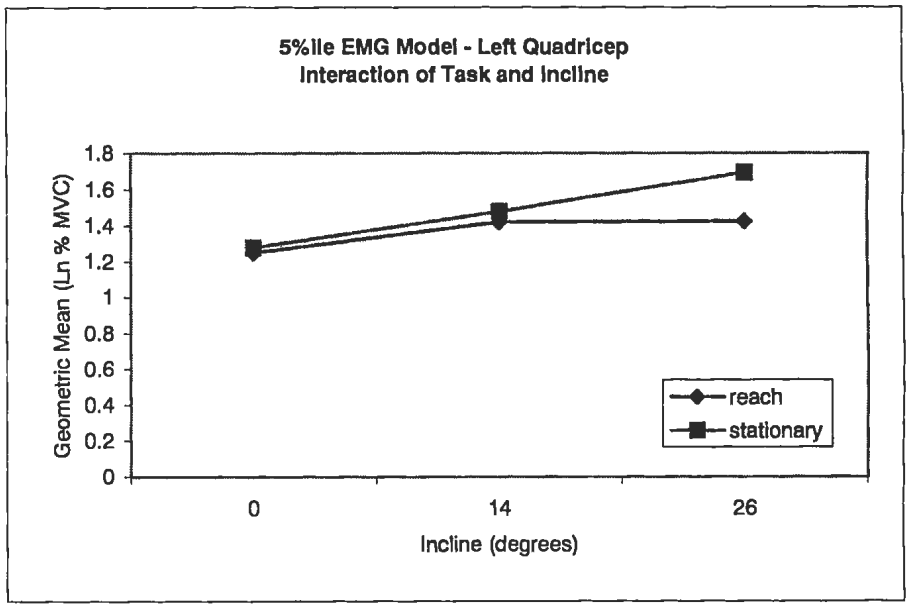


Figure S-11. Interactions for 25%ile EMG Model - Sway Area and Sway Length





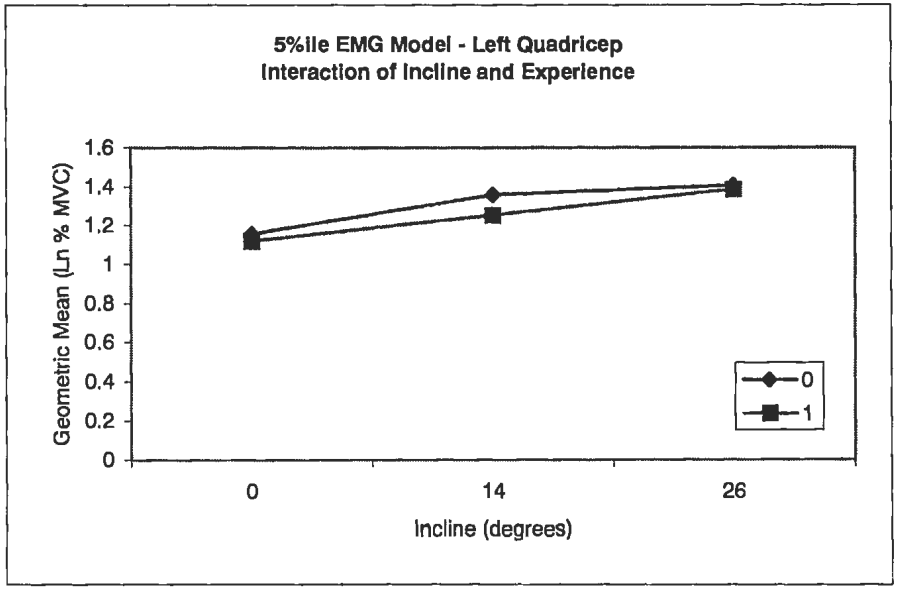
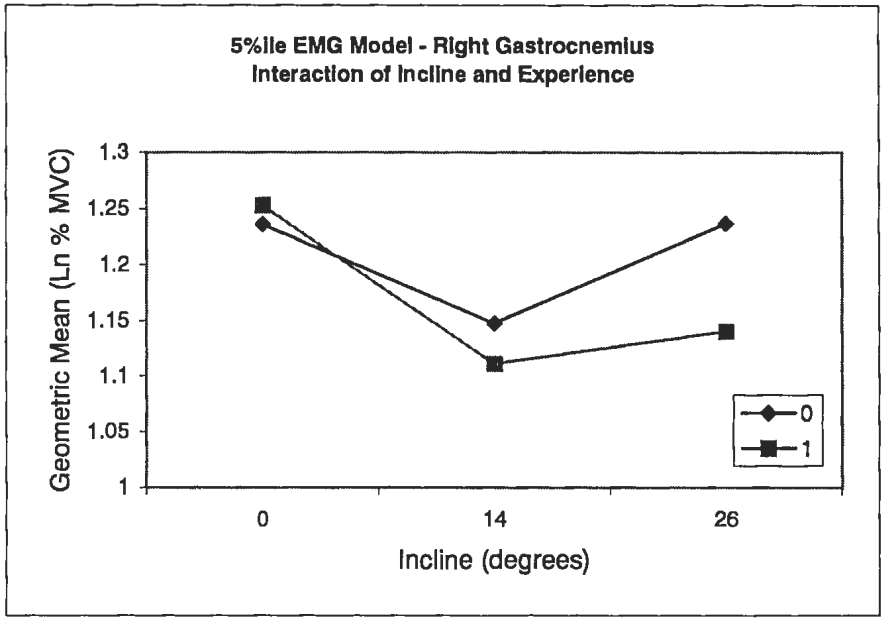
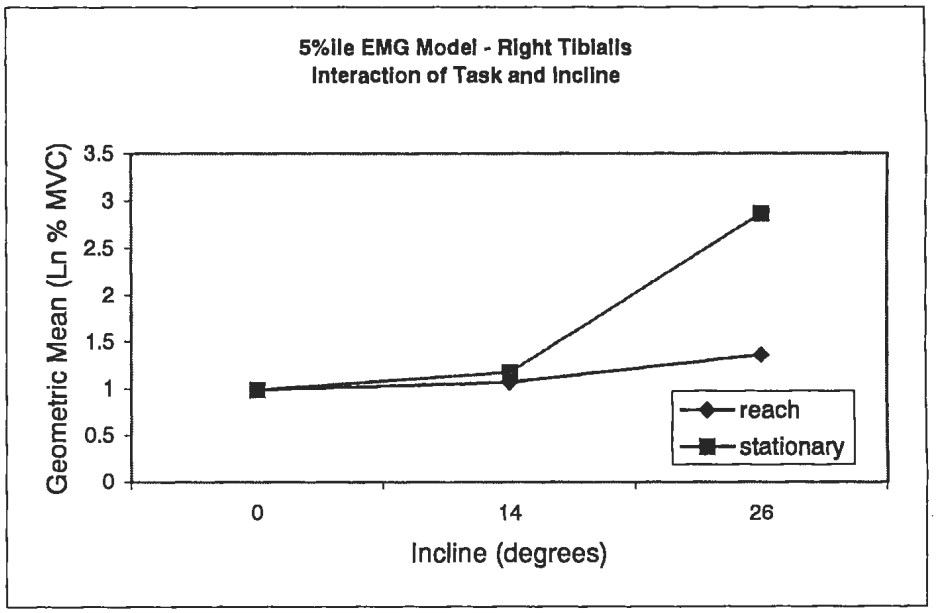
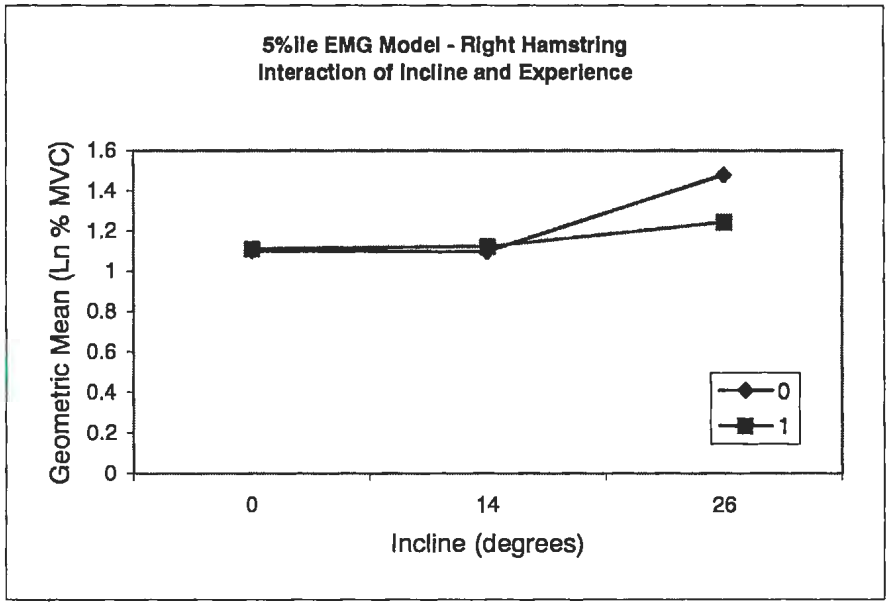


Figure S-12. Interactions for 5%ile EMG Model - Quadricep







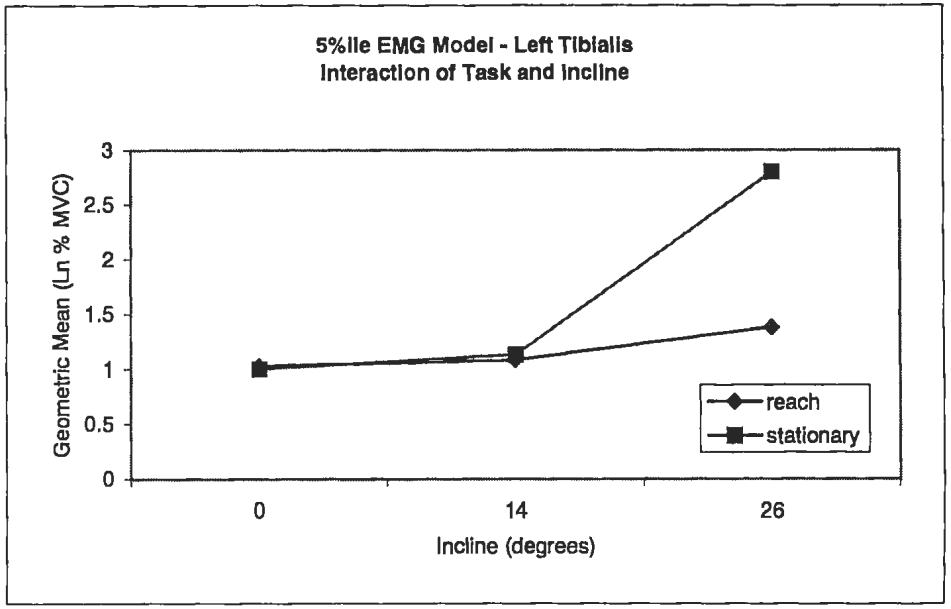
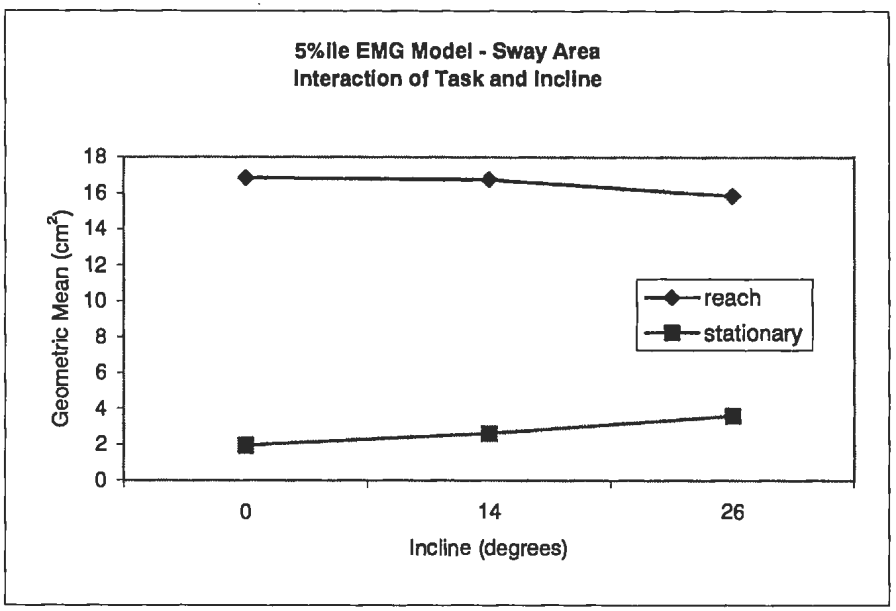
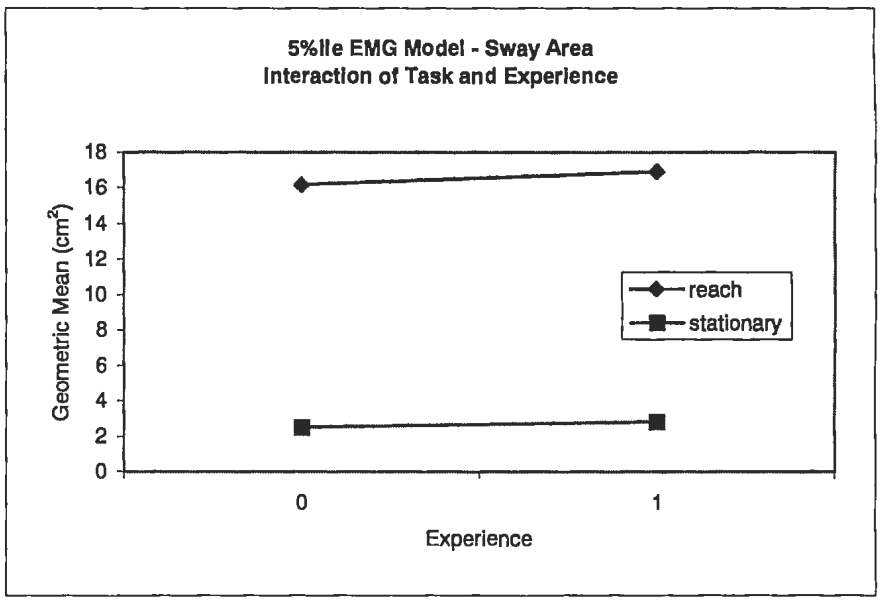
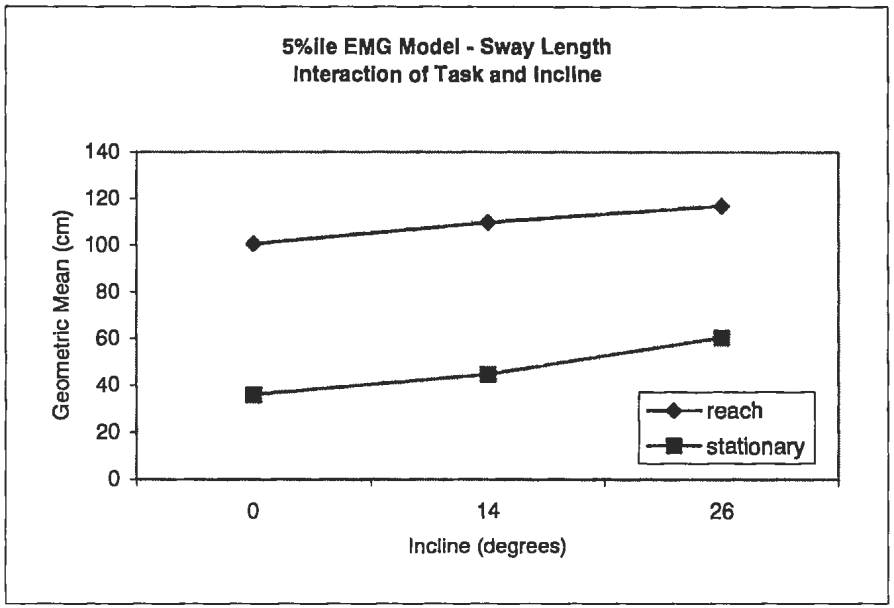


Figure S-13. Interactions for 5%ile EMG Model - Gastrocnemius, Hamstring, and Tibialis







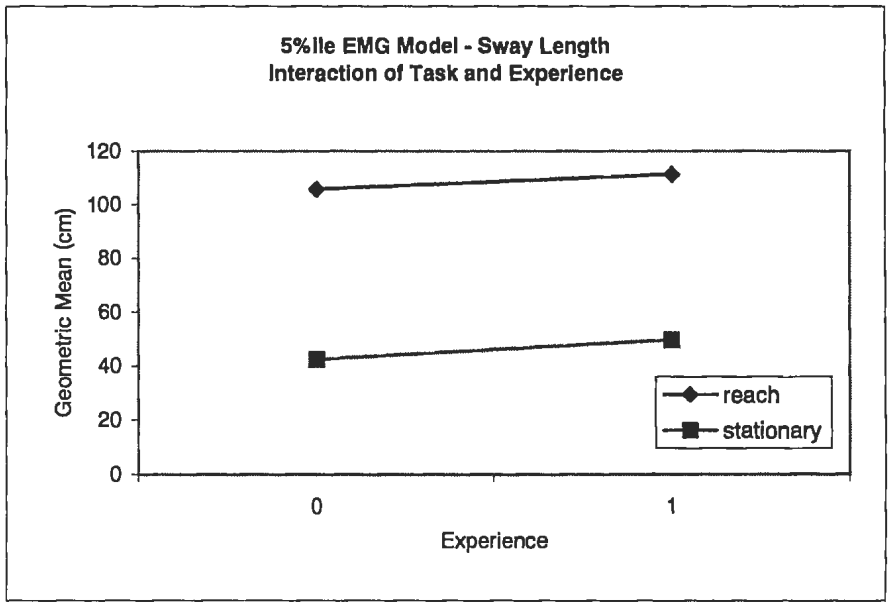


Figure S-14. Interactions for 5%ile EMG Model - Sway Area and Sway Length

Appendix T

ISCAN and Postural Sway Results

Table T-1. Range of P-values for testing the effects of experience, load, task, inclination and visual cue in the Structural Equation Model for Eye Movement and Postural Sway Outcomes.

Experimental Condition or Independent Variable	Ln RMS Vel.	Ln RMS Accel.	Ln Wt'd Eye Length	Logit Center Cue %	Logit 0-5" above/ below %	Logit 5-10" above/ below %	Logit 10-15" above/ below %	Ln Wt'd Mod Eye Area	Ln Wt'd 9.6" Clust. Dist.	Ln Sway Area	Ln Sway Length	Ln Excur. in the ML (X) direction	Ln Excur. in the AP (Y) direction
Range of R^2 Values	0.14 - 0.15	0.14	0.11	0.05	0.02	0.05 - 0.06	0.02	0.09 - 0.11	0.20 - 0.22	0.74 - 0.76	0.69	0.54 - 0.55	0.73 - 0.74
Work Experience Variables:													
Experienced vs. Inexperienced	**0.03**	**0.002**	**0.0002**	**0.0003**	0.24	**0.01**	0.82	**0.03**	**0.002**	0.52	0.96	0.13	0.93
Months of Work Experience	**0.0001**	0.74	**0.0001**	**0.0001**	0.16	0.59	0.65	0.42	**0.008**	**0.0001**	0.60	**0.02**	0.34
Hours of Work Activity	0.60	**0.006**	**0.0001**	**0.0001**	**0.02**	0.24	0.61	**0.0001**	0.14	**0.0001**	0.40	**0.005**	**0.0004**
Load Variables:													
Fatiguing Task Performed (Full vs. Half vs. None)	0.70 - 0.72	0.60 - 0.63	0.34 - 0.39	0.97 - 0.99	0.46 - 0.47	0.89 - 0.92	0.80 - 0.81	0.89 - 0.90	0.58 - 0.68	0.91- 0.99	0.50 - 0.86	0.42 - 0.86	0.97 - 0.99
Experimental Conditions:													
Task (Reach vs. Stationary)	**0.0001**	**0.0001**	**0.0001**	0.07 - 0.51	0.59 - 0.60	**0.01** - 0.92	**0.006-0.01**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Inclination (0 vs. 14 vs. 26 degrees)	**0.03 – 0.05**	0.08 - 0.12	**0.005 - 0.01**	**0.002 - 0.02**	**0.01 - 0.02**	0.32 - 0.37	0.12 - 0.14	0.13 - 0.14	0.90 - 0.96	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Visual Cue	0.35 - 0.99	0.26 - 0.77	0.13 - 0.16	**0.005 - 0.01**	0.61 - 0.62	**0.0001**	**0.009-0.01**	**0.02 - 0.03**	**0.02 - 0.03**	0.12 0.41	**0.0001-0.0008**	0.20 - 0.94	0.11 - 0.93

Experimental Condition or Independent Variable	Ln RMS Vel.	Ln RMS Accel.	Ln Wt'd Eye Length	Logit Center Cue %	Logit 0-5" above/ below %	Logit 5-10" above/ below %	Logit 10-15" above/ below %	Ln Wt'd Mod Eye Area	Ln Wt'd 9.6" Clust. Dist.	Ln Sway Area	Ln Sway Length	Ln Excur. in the ML (X) direction	Ln Excur. in the AP (Y) direction
Interactions of Experience Variables:													
Experience * Task		0.004											
Months on Job * Task						0.007			0.0003				
Months on Job* Quad Strength		0.003											
Months on Job * Ham Strength		0.04								0.0001			
Months on Job * Gastroc Strength									0.009				
Activity * Task				0.008					0.003		0.0006		0.004
Interactions of Experimental Conditions:													
Inclination * Cue	0.02 (1)	0.02 (1)											
Inclination* Task			0.02 - 0.03 (3)							0.0001 (3)	0.0001 (3)	0.0001 (3)	0.0001 (3)
Task*cue				0.02 (3)								0.0003 - 0.02 (2)	

Table T-2. Least Square Means for eye movement and postural sway variables for median of the three SEM's.

RMS_VELOCITY	Geometric Mean	Geometric Standard Error
Exp0	801.83	1.21
Exp1	669.21	1.22
Task reach	1021.47	1.20
Task stat	524.90	1.19
Incline 0	771.24	1.20
Incline14	677.22	1.20
Incline 26	751.37	1.20
Cue no	746.73	1.20
Cue yes	718.02	1.20
Load full	827.58	1.09
Load half	839.24	1.09
Load none	562.39	1.61
incline(0)*cue(no)	802.39	1.20
incline(0)*cue(yes)	741.22	1.21
incline(14)*cue(no)	667.67	1.20
incline(14)*cue(yes)	688.63	1.20
incline(26)*cue(no)	778.37	1.20
incline(26)*cue(yes)	725.82	1.20

RMS_ACCELERATION	Geometric Mean	Geometric Standard Error
Exp0	2065.86	1.12
Exp1	1571.05	1.12
Task reach	2506.64	1.09
Task stat	1294.66	1.09
Incline 0	1853.81	1.09
Incline14	1725.20	1.09
Incline 26	1828.22	1.09
Cue no	1829.14	1.09
Cue yes	1774.19	1.09
Load full	1809.31	1.09
Load half	1799.74	1.09
Load none	1795.43	1.09
task (reach) * exp (0)	2808.48	1.12
task (reach) * exp (1)	2237.24	1.13
task (stationary) * exp (0)	1519.44	1.12
task (stationary) * exp (1)	1103.12	1.13
incline(0)*cue(no)	2048.58	1.10
incline(0)*cue(yes)	1813.11	1.10
incline(14)*cue(no)	1702.07	1.10
incline(14)*cue(yes)	1834.45	1.10
incline(26)*cue(no)	1921.19	1.10
incline(26)*cue(yes)	1866.65	1.10

WT EYE LENGTH	Geometric Mean	Geometric Standard Error
Exp0	23.09	1.12
Exp1	16.11	1.12
Task reach	24.94	1.09
Task stat	14.92	1.09
Incline 0	19.37	1.09
Incline14	18.55	1.09
Incline 26	19.97	1.09
Cue no	20.00	1.09
Cue yes	18.61	1.09
Load full	19.07	1.09
Load half	19.44	1.09
Load none	19.36	1.09
task (reach) * incline (0)	25.91	1.10
task (reach) * incline (14)	25.07	1.10
task (reach) * incline (26)	23.87	1.09
task (stationary) * incline (0)	14.48	1.10
task (stationary) * incline (14)	13.73	1.10
task (stationary) * incline (26)	16.71	1.09

CENTER %	Geometric Mean	Geometric Standard Error
Exp0	6.40	12.07
Exp1	6.94	12.35
Task reach	7.11	11.50
Task stat	6.25	11.51
Incline 0	8.59	11.64
Incline14	6.67	11.66
Incline 26	5.17	11.50
Cue no	4.53	11.52
Cue yes	9.71	11.49
Load full	6.42	11.68
Load half	6.34	11.60
Load none	7.29	11.59
task (reach) * cue (no)	4.72	11.68
task (reach) * cue (yes)	10.57	11.68
task (stationary) * cue (no)	4.34	11.71
task (stationary) * cue (yes)	8.90	11.66

0-5" above/below center %	Geometric Mean	Geometric Standard Error
Exp0	13.71	11.67
Exp1	14.59	11.90
Task reach	15.05	11.12
Task stat	13.28	11.12
Incline 0	17.52	11.24
Incline14	13.81	11.27
Incline 26	11.60	11.12
Cue no	13.74	11.13
Cue yes	14.55	11.11
Load full	13.66	11.20
Load half	13.72	11.22
Load none	15.08	11.20

5-10" above/below center %	Geometric Mean	Geometric Standard Error
Exp0	6.22	10.11
Exp1	4.67	10.32
Task reach	5.68	10.63
Task stat	4.09	10.65
Incline 0	4.65	10.81
Incline14	5.14	10.82
Incline 26	4.69	10.66
Cue no	6.80	10.65
Cue yes	3.40	10.63
Load full	5.19	10.75
Load half	4.85	10.77
Load none	4.46	10.75

10-15" above/below center %	Geometric Mean	Geometric Standard Error
Exp0	3.45	11.07
Exp1	2.57	11.34
Task reach	3.50	10.34
Task stat	2.53	10.35
Incline 0	2.57	10.49
Incline14	3.57	10.50
Incline 26	2.88	10.47
Cue no	3.58	10.34
Cue yes	2.48	10.35
Load full	3.11	10.48
Load half	3.08	10.49
Load none	2.76	10.47

WT EYE AREA	Geometric Mean	Geometric Standard Error
Exp0	14.82	1.16
Exp1	10.49	1.18
Task reach	24.85	1.13
Task stat	6.26	1.14
Incline 0	12.74	1.14
Incline14	12.05	1.14
Incline 26	12.63	1.14
Cue no	13.44	1.14
Cue yes	11.57	1.13
Load full	12.63	1.14
Load half	12.70	1.14
Load none	12.09	1.14

WT 9.6" CLUSTER DISTANCE	Geometric Mean	Geometric Standard Error
Exp0	18.64	1.09
Exp1	15.91	1.09
Task reach	21.27	1.08
Task stat	12.11	1.08
Incline 0	15.50	1.09
Incline14	15.85	1.09
Incline 26	16.83	1.08
Cue no	16.75	1.08
Cue yes	15.37	1.08
Load full	16.18	1.08
Load half	15.52	1.08
Load none	16.46	1.08

SWAY AREA	Geometric Mean	Geometric Standard Error
Exp0	6.45	1.07
Exp1	6.54	1.07
Task reach	16.19	1.05
Task stat	2.60	1.05
Incline 0	5.71	1.05
Incline14	6.50	1.06
Incline 26	7.38	1.05
Cue no	6.70	1.05
Cue yes	6.30	1.05
Load full	6.49	1.05
Load half	6.46	1.05
Load none	6.52	1.05
task (reach) * incline (0)	16.71	1.06
task (reach) * incline (14)	16.49	1.06
task (reach) * incline (26)	15.40	1.06
task (stationary) * incline (0)	1.95	1.06
task (stationary) * incline (14)	2.56	1.06
task (stationary) * incline (26)	3.53	1.06

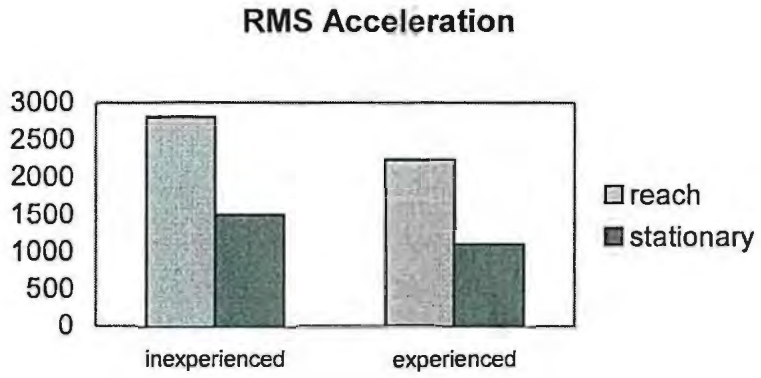
SWAY LENGTH	Geometric Mean	Geometric Standard Error
Exp0	67.03	1.03
Exp1	73.06	1.03
Task reach	107.71	1.02
Task stat	45.47	1.02
Incline 0	60.27	1.02
Incline14	68.66	1.02
Incline 26	82.82	1.02
Cue no	72.16	1.02
Cue yes	67.87	1.02
Load full	70.47	1.02
Load half	69.99	1.02
Load none	69.50	1.02
task (reach) * incline (0)	100.95	1.03
task (reach) * incline (14)	107.19	1.03
task (reach) * incline (26)	115.54	1.03
task (stationary) * incline (0)	35.99	1.03
task (stationary) * incline (14)	44.01	1.03
task (stationary) * incline (26)	59.36	1.03
task (reach) * exp (0)	106.42	1.03
task (reach) * exp (1)	109.01	1.03
task (stationary) * exp (0)	42.22	1.03
task (stationary) * exp (1)	48.97	1.03

Excursion in the ML direction (X)	Geometric Mean	Geometric Standard Error
Exp0	2.33	1.04
Exp1	2.51	1.05
Task reach	3.66	1.04
Task stat	1.60	1.04
Incline 0	2.06	1.04
Incline14	2.44	1.04
Incline 26	2.82	1.04
Cue no	2.45	1.04
Cue yes	2.39	1.04
Load full	2.41	1.04
Load half	2.39	1.04
Load none	2.46	1.04
task (reach) * incline (0)	3.46	1.04
task (reach) * incline (14)	3.65	1.04
task (reach) * incline (26)	3.90	1.04
task (stationary) * incline (0)	1.24	1.04
task (stationary) * incline (14)	1.63	1.04
task (stationary) * incline (26)	2.04	1.04
task (reach) * cue (no)	3.77	1.04
task (reach) * cue (yes)	3.55	1.04
task (stationary) * cue (no)	1.60	1.04
task (stationary) * cue (yes)	1.61	1.04

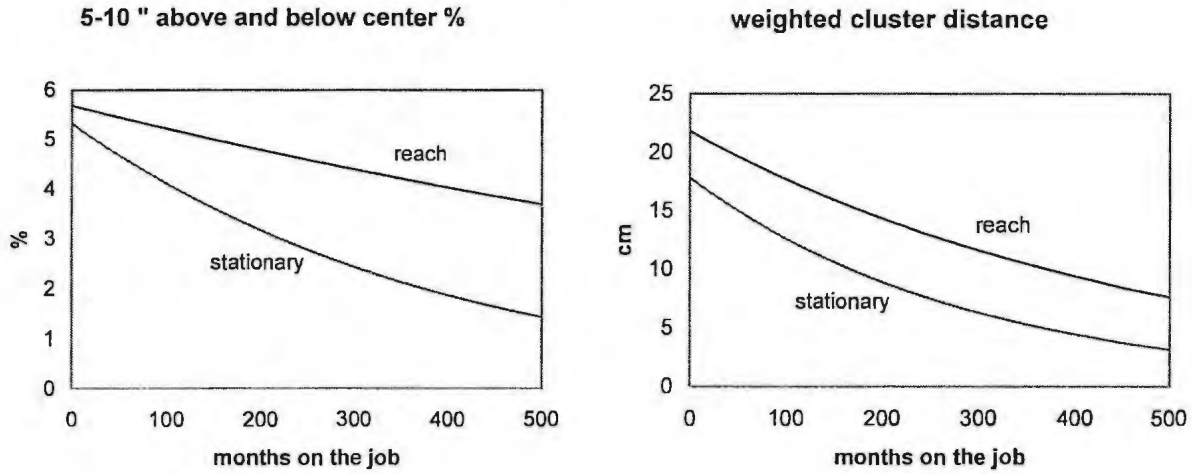
Excursion in the AP direction (Y)	Geometric Mean	Geometric Standard Error
Exp0	4.73	1.03
Exp1	4.82	1.03
Task reach	8.06	1.02
Task stat	2.83	1.02
Incline 0	4.78	1.02
Incline14	4.70	1.02
Incline 26	4.82	1.04
Cue no	4.86	1.02
Cue yes	4.68	1.04
Load full	4.80	1.02
Load half	4.78	1.02
Load none	4.72	1.02
task (reach) * incline (0)	8.61	1.03
task (reach) * incline (14)	8.16	1.03
task (reach) * incline (26)	7.48	1.03
task (stationary) * incline (0)	2.66	1.03
task (stationary) * incline (14)	2.71	1.03
task (stationary) * incline (26)	3.13	1.03

Table T-3. P-values for Significant Effect of Eye Movement Variables on Postural Sway from Structural Models with Experience/Inexperienced, Months of job experience and Hours of Work Activity (parenthesis indicate the number of models the variable was significant in).

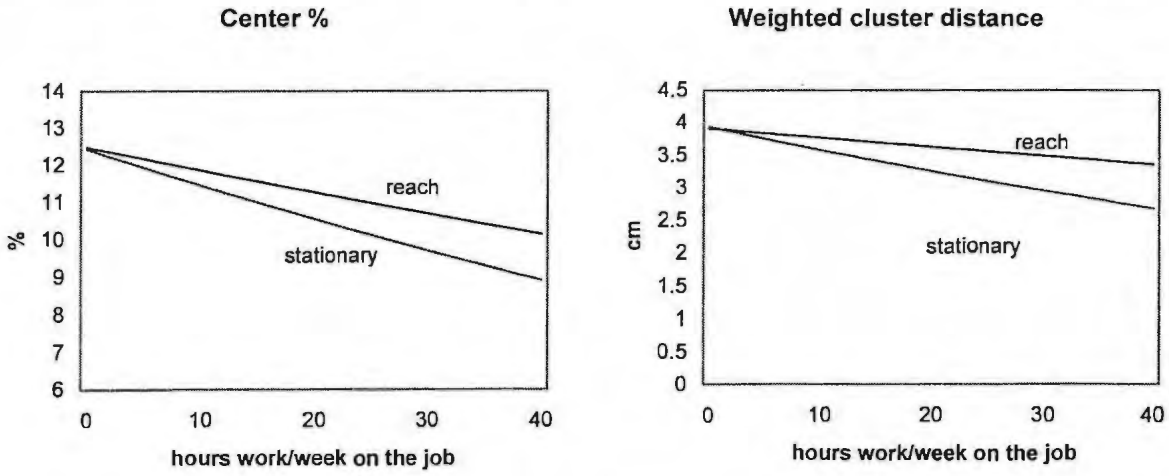
	Ln Sway Area	**Ln Sway Length**	**Ln Excur. in the ML (X) direction**	**Ln Excur. in the AP (Y) direction**
Logit Center Cue %	0.001 (1)	--	--	--
Logit 0-5" above/ below %	--	--	0.0001 (2)	--
Logit 10-15" above / below %	--	0.0001 (1)	--	0.0001 (1)
Ln Wt'd 9.6" Cluster Distance	--	--	0.03 (1)	--
Ln RMS Velocity	0.009 (1)	--	--	--



a. Experience and task interaction for RMS acceleration of eye movement.

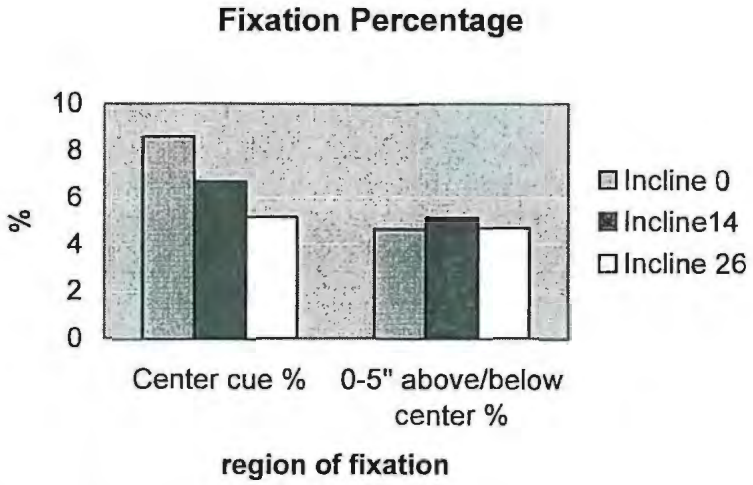


b. Interaction of months on the job and task for fixations 5-10" above/below center cue and weighted cluster distance.

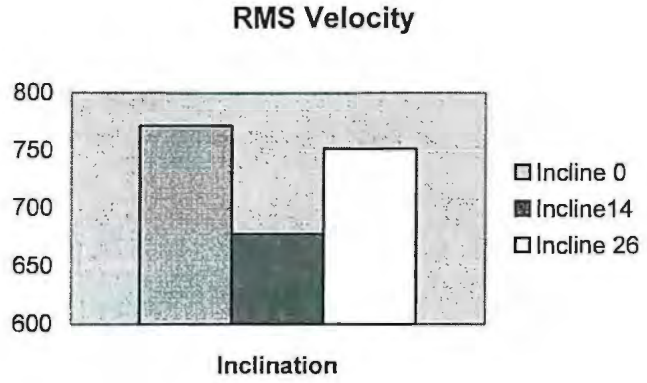


c. Interaction of hours work/week and task for center fixation % and weighted cluster distance.

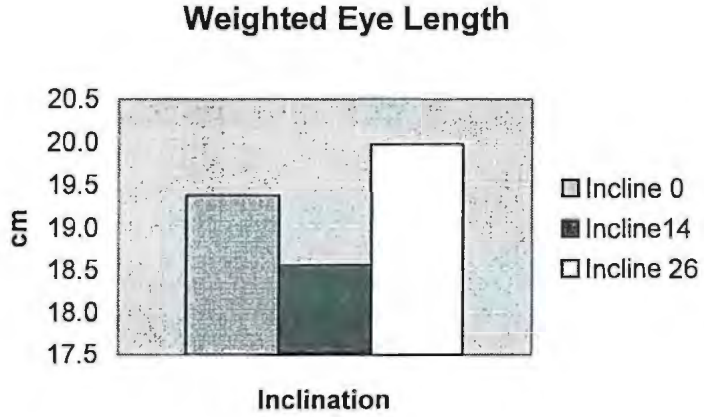
Figure T-1. Interactions between experience variables and task.



a. Fixation percentage for the center cue and near the center cue (0-5") by incline.



b. RMS velocity by incline.



c. Weighted eye length by incline.

Figure T-2. Effect of inclination on eye movement variables.

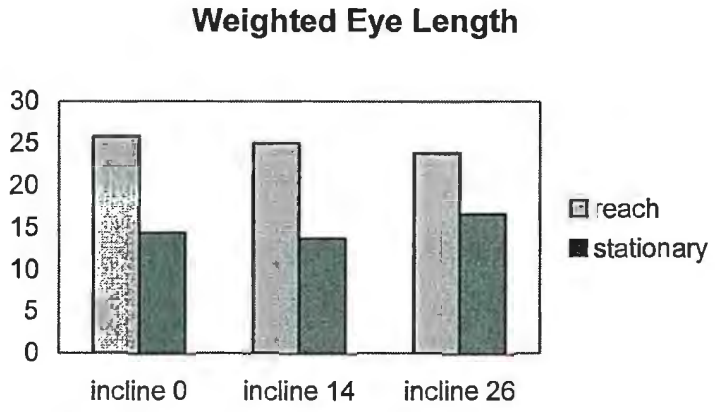
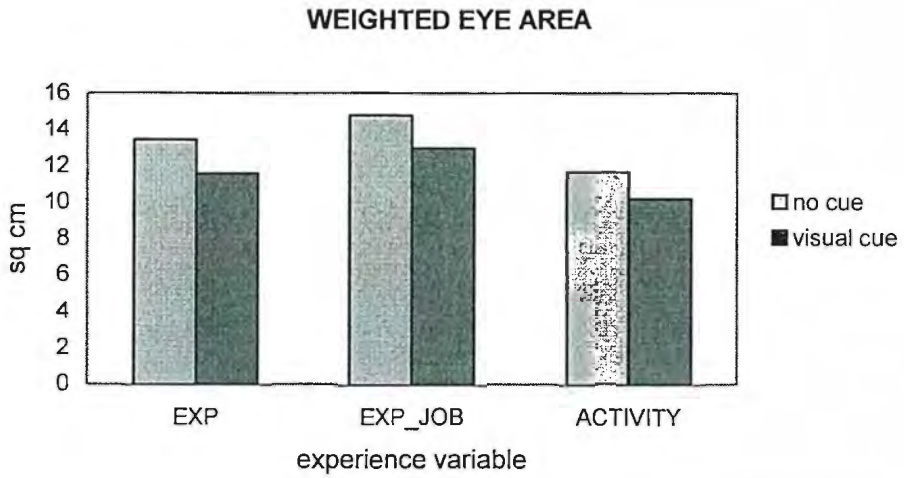
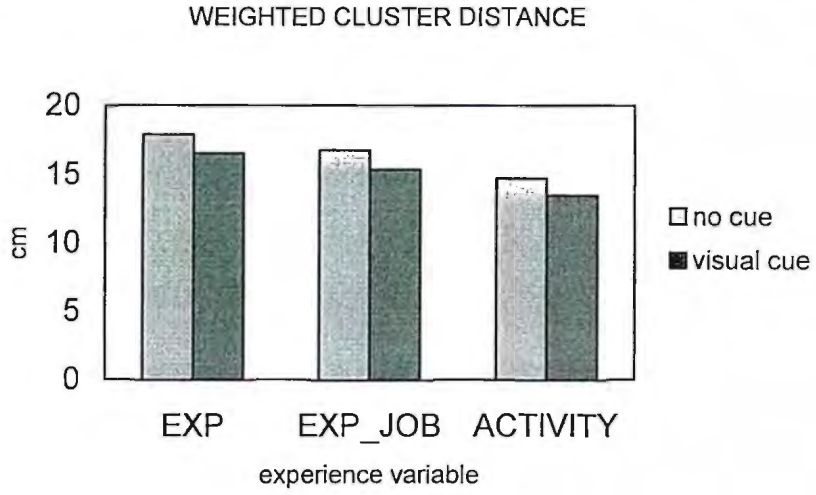


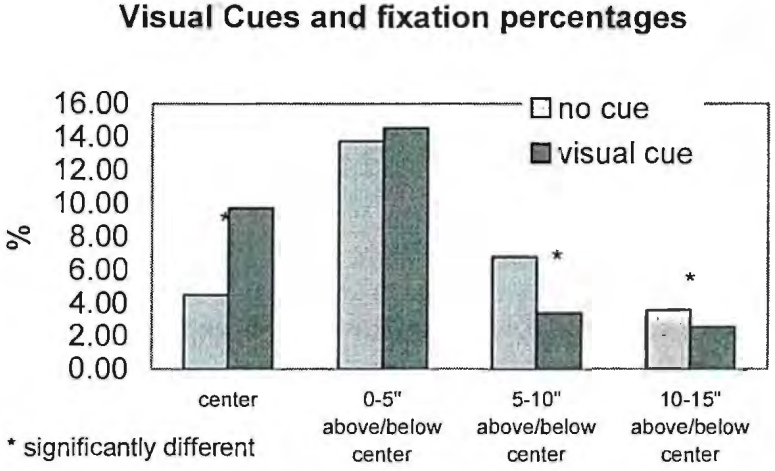
Figure T-3. Interaction of incline and task for weighted eye length.



a. Weighted eye area by presence of visual cue for each experience model.

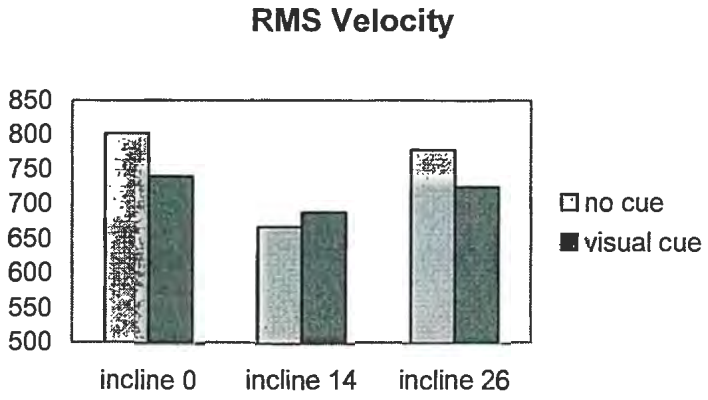


b. Weighted cluster distance by presence of visual cue for each experience model

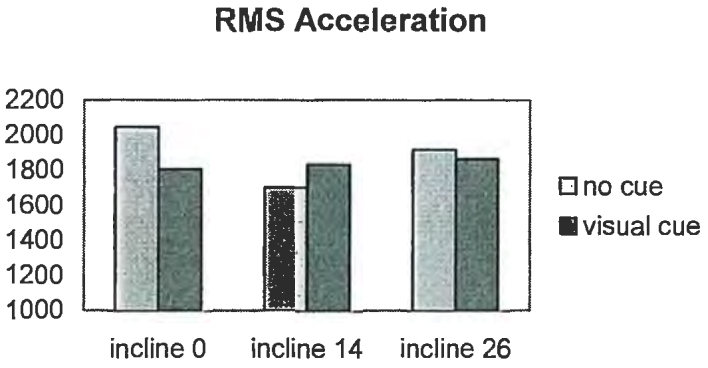


c. Fixation percentage for different regions by presence of visual cue.

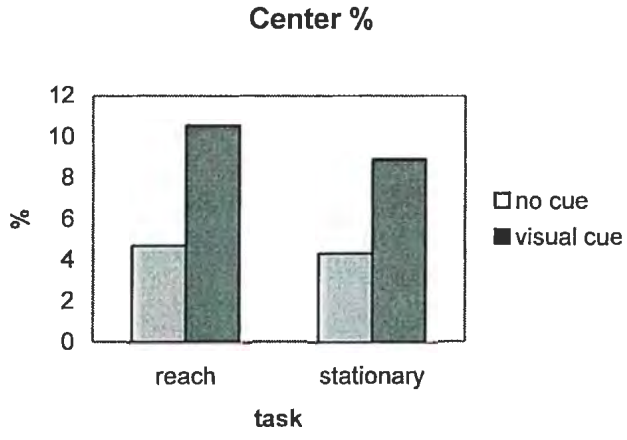
Figure T-4. Eye movement variables and visual cue effect.



a. Interaction of incline and cue on RMS velocity of eye movement.



b. Interaction of incline and cue on RMS acceleration of eye movement.



c. Interaction of task and cue on fixation percentage on center cue.

Figure T-5. Interactions with visual cues.

Appendix U

Indices of Postural Stability Results

Table U1. Stability Indices based on CG data

Experimental Condition or Independent Variable	**IPSB Average**	**IPSB Minimum**	**IPSB Maximum**	**Log IPSB RMS**	**Log WRTI**	**Log SAR**
Work Experience Variables:						
Experienced vs. Inexperienced	**0.03**	0.06	0.39	**0.04**	**0.037**	0.91
Months of Work Experience	0.68	0.76	0.17	0.73	0.43	0.87
Hours of Work Activity	0.09	0.14	0.28	0.12	**0.018**	0.92
Load Variables:						
Fatiguing Task Performed (Full vs. Half vs. None)	0.09-0.10	0.57-0.60	0.19-0.22	0.067 0.076	0.65	0.74
Experimental Conditions:						
Task (Reach vs. Stationary)	**0.0008**	**0.0001**	**0.0001**	**0.0001**	0.26-0.28	**0.0001**
Inclination (0 vs. 14 vs. 26 degrees)	**0.0001**	**0.0005**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Visual Cue	0.69	0.85-0.86	0.92-0.97	0.91	0.37-0.38	**0.0016**
Interactions of Experience Variables:						
Experience * Incline					**0.048**	
Experience * Task			**0.0001**			
Experience * Load			**0.039**			
Months of work experience * Task			**0.0019**			
Hours of work activity * Task			**0.0001**			
Interactions of Experimental Conditions:						
Task * Incline	**0.0091-0.0094** (3)	**0.0002-0.0003** (3)		**0.0097-0.01** (3)	**0.0037-0.0041** (3)	**0.0001** (3)
Task * Load						**0.046-0.047** (3)

Table U-2. Stability Indices based on CG data.

Experimental Condition or Independent Variable	**IPSB Average**	**IPSB Minimum**	**IPSB Maximum**	**Log IPSB RMS**	**Log WRTI**	**Log SAR**
Work Experience Variables:						
Experienced vs. Inexperienced	**0.039**	0.80	0.27	0.11	**0.0024**	0.28
Months of Work Experience	0.53	0.78	0.99	0.66	0.26	0.87
Hours of Work Activity	0.099	0.69	0.55	0.19	**0.011**	0.14
Load Variables:						
Fatiguing Task Performed (Full vs. Half vs. None)	0.074	0.57	**0.037-0.039**	0.17	0.08-0.13	0.73-0.74
Experimental Conditions:						
Task (Reach vs. Stationary)	**0.064-0.065**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Inclination (0 vs. 14 vs. 26 degrees)	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	0.38-0.39
Visual Cue	0.19	0.22-0.23	0.30-0.32	0.087-0.089	0.13-0.15	**0.037-0.04**
Interactions of Experience Variables:						
Experience * Incline					**0.037**	
Months of work experience * Task					**0.04**	**0.001**
Hours of work activity *Incline		**0.033**			**0.04**	
Hours of work activity * Task			**0.012**			
Interactions of Experimental Conditions:						
Task * Incline		**0.0031-0.0035** (3)	**0.0001** (3)			**0.0092-0.01** (3)

Table U-3. LSM for CG-based IPSB

IPSB Average	**Mean**	**Std. Error**
Exp0	0.67	0.018
Exp1	0.73	0.018
Task reach	0.71	0.013
Task stat	0.69	0.013
Incline 0	0.67	0.014
Incline14	0.63	0.014
Incline 26	0.79	0.014
Cue no	0.70	0.013
Cue yes	0.69	0.013
Load full	0.71	0.014
Load half	0.70	0.014
Load none	0.69	0.014

IPSB Maximum	**Mean**	**Std. Error**
Exp0	0.82	0.018
Exp1	0.85	0.018
Task reach	0.92	0.013
Task stat	0.75	0.013
Incline 0	0.82	0.014
Incline14	0.76	0.014
Incline 26	0.92	0.92
Cue no	0.84	0.84
Cue yes	0.83	0.83
Load full	0.84	0.84
Load half	0.84	0.84
Load none	0.82	0.82
Task*Incline_Reach 0	0.93	0.02
Task*Incline_Reach 14	0.86	0.02
Task*Incline_Reach 26	0.97	0.97
Task*Incline_stationary 0	0.71	0.71
Task*Incline_stationary 14	0.67	0.67
Task*Incline_stationary 26	0.86	0.86

IPSB Minimum	**Mean**	**Std. Error**
Exp0	0.48	0.016
Exp1	0.49	0.016
Task reach	0.37	0.013
Task stat	0.60	0.013
Incline 0	0.49	0.015
Incline14	0.43	0.015
Incline 26	0.53	0.015
Cue no	0.49	0.013
Cue yes	0.48	0.013
Load full	0.49	0.495
Load half	0.48	0.480
Load none	0.48	0.015
Task*Incline_Reach 0	0.39	0.019
Task*Incline_Reach 14	0.34	0.020
Task*Incline_Reach 26	0.38	0.019
Task*Incline_stationary 0	0.59	0.019
Task*Incline_stationary 14	0.52	0.019
Task*Incline_stationary 26	0.68	0.019

Log IPSB RMS	Geometric Mean	Geometric Std. Error
Exp0	6.37	1.03
Exp1	6.89	1.03
Task reach	11.97	1.03
Task stat	3.67	1.03
Incline 0	6.41	1.03
Incline14	6.05	1.03
Incline 26	7.49	1.03
Cue no	6.71	1.03
Cue yes	6.53	1.03
Load full	6.75	1.03
Load half	6.60	1.03
Load none	6.51	1.03

Log WRTI	Geometric Mean	Geometric Std. Error
Exp0	51.77	1.15
Exp1	26.96	1.15
Task reach	122.30	1.11
Task stat	11.41	1.11
Incline 0	44.21	1.12
Incline14	56.91	1.12
Incline 26	20.39	1.12
Cue no	35.66	1.11
Cue yes	39.13	1.11
Load full	34.38	1.12
Load half	37.53	1.12
Load none	40.37	1.12

Log SAR	Geometric Mean	Geometric Std. Error
Exp0	0.07	1.05
Exp1	0.07	1.05
Task reach	0.17	1.04
Task stat	0.03	1.04
Incline 0	0.07	1.04
Incline14	0.07	1.04
Incline 26	0.07	1.04
Cue no	0.07	1.04
Cue yes	0.07	1.04
Load full	0.07	1.04
Load half	0.07	1.04
Load none	0.07	1.04
Task*Incline_Reach 0	0.19	1.04
Task*Incline_Reach 14	0.17	1.04
Task*Incline_Reach 26	0.17	1.04
Task*Incline_stationary 0	0.03	1.04
Task*Incline_stationary 14	0.03	1.04
Task*Incline_stationary 26	0.03	1.04

Table U-4. LSM for CP-based IPSB

IPSB Average	Mean	Std. Error
Exp0	0.60	0.026
Exp1	0.67	0.026
Task reach	0.65	0.022
Task stat	0.63	0.022
Incline 0	0.71	0.022
Incline14	0.60	0.022
Incline 26	0.60	0.022
Cue no	0.64	0.022
Cue yes	0.64	0.022
Load full	0.65	0.014
Load half	0.66	0.014
Load none	0.61	0.052
Task*Incline_Reach 0	0.71	0.023
Task*Incline_Reach 14	0.61	0.023
Task*Incline_Reach 26	0.62	0.023
Task*Incline_stationary 0	0.71	0.022
Task*Incline_stationary 14	0.58	0.022
Task*Incline_stationary 26	0.58	0.023

IPSB Maximum	Mean	Std. Error
CAFFEINE 1	0.87	0.015
CAFFEINE 2	0.83	0.014
Exp0	0.84	0.019
Exp1	0.86	0.019
Task reach	0.96	0.013
Task stat	0.74	0.013
Incline 0	0.92	0.013
Incline14	0.80	0.014
Incline 26	0.83	0.013
Cue no	0.85	0.013
Cue yes	0.85	0.013
Load full	0.85	0.014
Load half	0.86	0.013
Load none	0.85	0.013
Task*EXP_Reach	0.97	0.020
Task*EXP_Reach	0.95	0.020
Task*EXP_stationary	0.71	0.020
Task*EXP_stationary	0.77	0.020
Task*EXP_Full	0.82	0.020
Task*EXP_Full	0.87	0.020
Task*EXP_HALF	0.85	0.020
Task*EXP_HALF	0.87	0.020
Task*EXP_NONE	0.84	0.020
Task*EXP_NONE	0.85	0.020

IPSB Minimum	Mean	Std. Error
Exp0	0.38	0.023
Exp1	0.44	0.023
Task reach	0.33	0.018
Task stat	0.49	0.017
Incline 0	0.45	0.018
Incline14	0.40	0.018
Incline 26	0.39	0.018
Cue no	0.41	0.018
Cue yes	0.41	0.018
Load full	0.42	0.019
Load half	0.42	0.019
Load none	0.40	0.018
Task*Incline_Reach 0	0.33	0.021
Task*Incline_Reach 14	0.32	0.021
Task*Incline_Reach 26	0.34	0.021
Task*Incline_stationary 0	0.56	0.021
Task*Incline_stationary 14	0.47	0.021
Task*Incline_stationary 26	0.45	0.021

Log IPSB RMS	Geometric Mean	Geometric Std. Error
Exp0	25.41	1.04
Exp1	28.06	1.04
Task reach	27.40	1.04
Task stat	25.98	1.04
Incline 0	29.86	1.04
Incline14	25.21	1.04
Incline 26	25.22	1.04
Cue no	26.69	1.04
Cue yes	26.66	1.04
Load full	26.91	1.02
Load half	27.56	1.02
Load none	25.61	1.09
Task*Incline_Reach 0	29.99	1.04
Task*Incline_Reach 14	26.09	1.04
Task*Incline_Reach 26	26.27	1.04
Task*Incline_stationary 0	29.74	1.04
Task*Incline_stationary 14	24.36	1.04
Task*Incline_stationary 26	24.21	1.04

Log SAR	Geometric Mean	Geometric Std. Error
Exp0	0.19	1.05
Exp1	0.19	1.05
Task reach	0.38	1.04
Task stat	0.09	1.04
Incline 0	0.17	1.04
Incline14	0.18	1.04
Incline 26	0.21	1.04
Cue no	0.19	1.04
Cue yes	0.18	1.04
Load full	0.19	1.04
Load half	0.18	1.04
Load none	0.19	1.04
Task*Incline_Reach 0	0.37	1.04
Task*Incline_Reach 14	0.38	1.04
Task*Incline_Reach 26	0.38	1.04
Task*Incline_stationary 0	0.08	1.04
Task*Incline_stationary 14	0.08	1.04
Task*Incline_stationary 26	0.12	1.04
Task*Load_Reach full	0.37	1.04
Task*Load_Reach half	0.38	1.04
Task*Load_Reach none	0.39	1.04
Task*Load_Stationary full	0.10	1.04
Task*Load_Stationary half	0.09	1.04
Task*Load_Stationary none	0.09	1.04

Log WRTI	Geometric Mean	Geometric Std. Error
Exp0	1286.01	1.18
Exp1	781.41	1.17
Task reach	1033.49	1.12
Task stat	972.33	1.12
Incline 0	564.93	1.13
Incline14	1420.27	1.13
Incline 26	1255.51	1.13
Cue no	1027.11	1.12
Cue yes	978.38	1.12
Load full	1039.92	1.13
Load half	984.66	1.13
Load none	983.78	1.13
Task*Incline_Reach 0	661.63	1.19
Task*Incline_Reach 14	1436.26	1.19
Task*Incline_Reach 26	1161.65	1.19
Task*Incline_stationary 0	482.36	1.19
Task*Incline_stationary 14	1404.45	1.19
Task*Incline_stationary 26	1356.82	1.19
Incline*EXP 0	740.04	1.14
Incline*EXP 0	431.30	1.14
Incline*EXP 14	1963.92	1.14
Incline*EXP 14	1027.11	1.14
Incline*EXP 26	1463.52	1.14
Incline*EXP 26	53.62	1.14

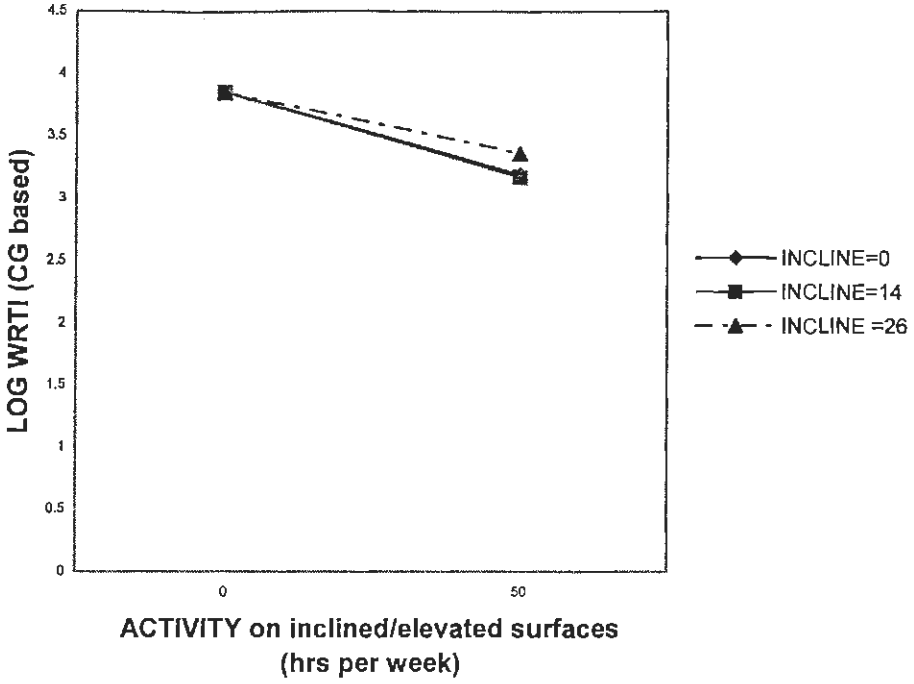


Figure U-A. Interaction of Incline and Activity on WRTI (CG)

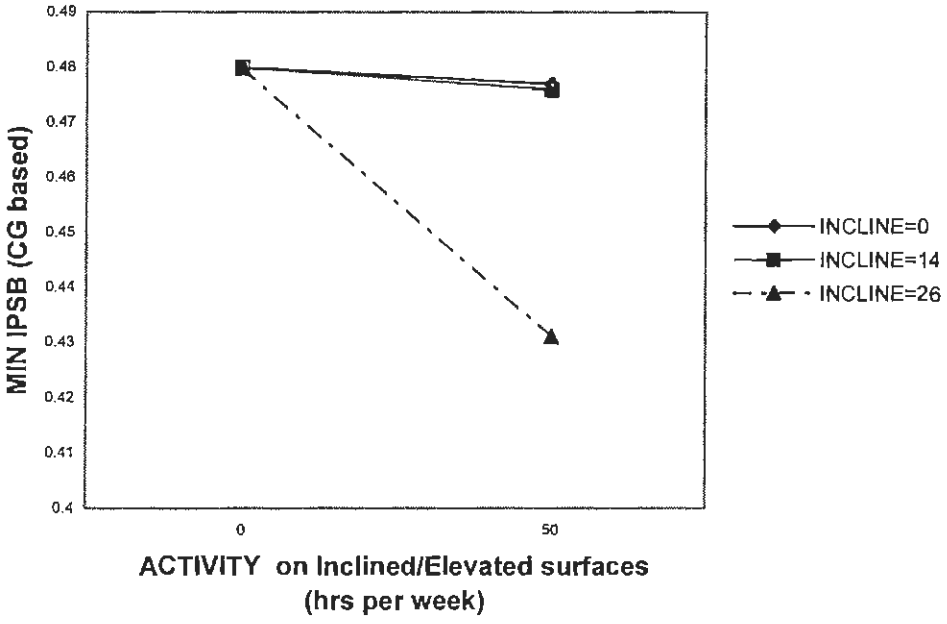


Figure U-B. Interaction of Activity and Incline on Min IPSB (CG).

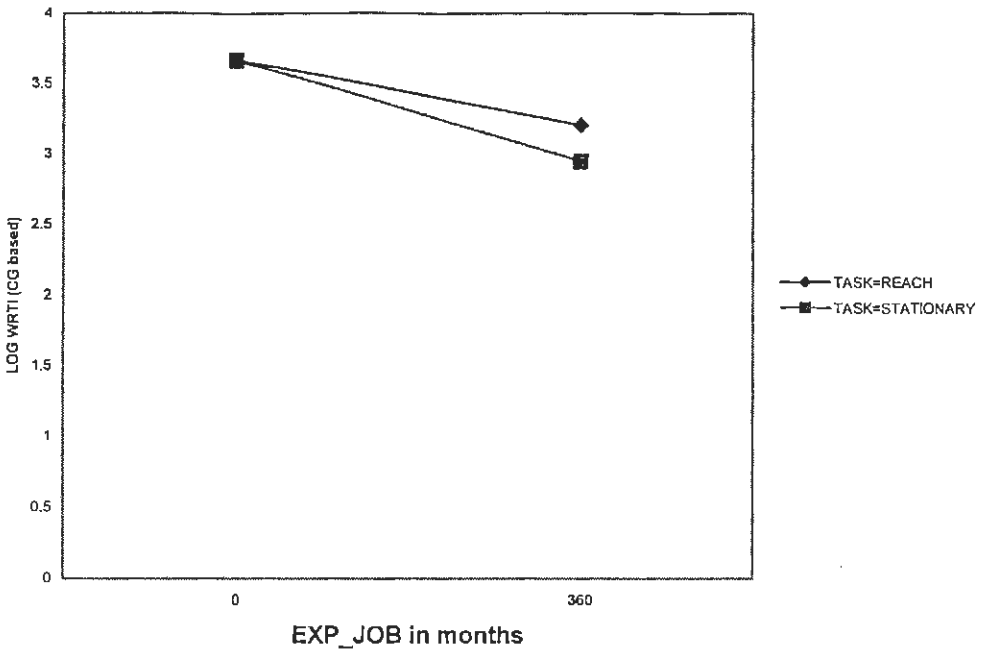


Figure U-C. Interaction of months on the job (exp_job) and task with WRTI (CG)

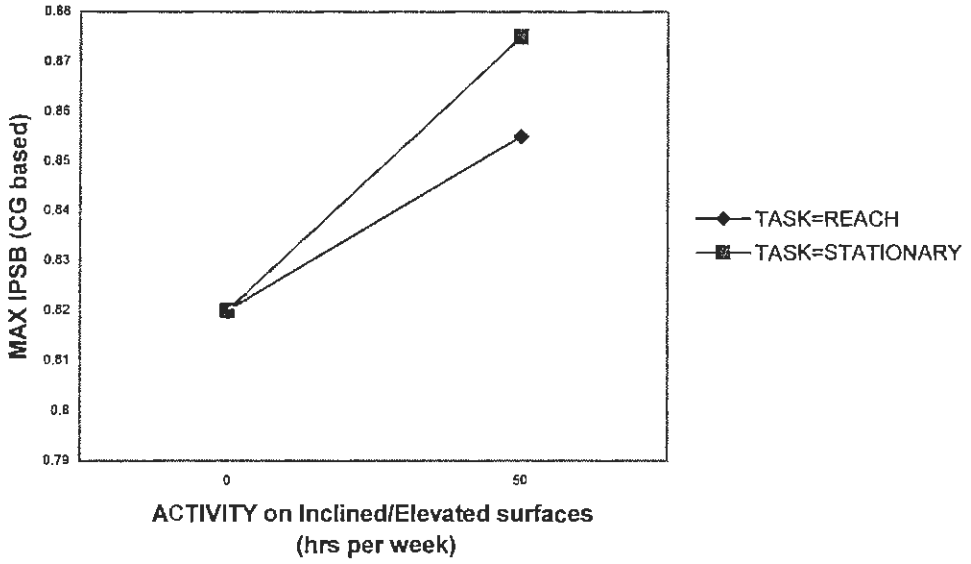


Figure U-D. Interaction of task and ACTIVITY for max IPSB (CG).