FINAL PERFORMANCE REPORT

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"POSTURAL STABILITY EFFECTS IN LOW SEAM MINING TASKS"

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LIST OF ABBREVIATIONS

Al	Aluminum
AMTI	Advanced Mechanical Technology Incorporated
AP	Anterior-Posterior
BMI	Body Mass Index
BOS	Base of Support
BP	Blood Pressure
CG	Center of Gravity
CNS	Central Nervous System
COF	Coefficient of Friction
COM	Center of Mass
CP	Center of Pressure
CV	Coefficient of Variation
DCOF	Dynamic Coefficient of Friction
DF	Degrees of Freedom
Excur	Excursion
Ex-X	Excursion X
Ex-Y	Excursion Y
fc	Foot candles
FSB	Functional Stability Boundary
GRF	Ground Reaction Forces
GRR	Ground Reaction Forces of Right Foot
GRL	Ground Reaction Forces of Left Foot
H/V	Horizontal Force / Vertical Force
IPSB	Index of Proximity to Stability Boundary
IRB	Institutional Review Board
L	Leather Steel-toe Boots
ML	Medio-lateral
MSHA	Mine Safety and Health Administration
MTP	Metatarsal phalange
N	Number
NIOSH	National Institute for Occupational Safety and Health
OR	Odds Ratio
PSOF	Rating of Perceived Sense of Fall
R	Rubber Steel-toe Boots
RPE	Rating of Perceived Exertion Scale
SA	Sway Area
SAR	Stability Area Ratio
SAS	Statistical Analysis System
SCOF	Static Coefficient of Friction
SD	Standard Deviation
SEM	Standard Error of Mean
SL	Sway Length
UMWA	United Mine Workers of America
WRTI	Weighted Residence Time Index

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ABSTRACT

The manual material handling tasks in underground low seam mines present a myriad of ergonomic risk factors, which place inordinate demands on miners' neuromuscular system. Literature reports that serious injuries associated with handling material and slips or falls accounted for 36.4% (highest) and 16.4% (second highest), respectively, of all serious injuries. The mining industry requires work in restricted postures in mines with low-ceiling heights (low-seam mines). Material handling in restricted posture will cause potential of loss of stability/balance to increase; therefore, lifting task analysis should include information about postural stability/balance. Currently such information does not exist for material handling in a static stooped/kneeling posture and dynamic (gait) stooped posture. The proposed study will provide this type of information. This information could be used for task analysis of material handling in mine site.

The overall purpose of the study was to quantify postural instability of low seam miners while carrying out mine related tasks under exposure to individual and combined risk factors of environmental lighting, surface condition and footwear used. For this study, a total of 25 miner subjects were tested. Subjects (both males and females) were recruited from the United Mine Workers of America, (UMWA) District 17, Local 2264, Pikeville, KY as well as mines in Middlesboro, KY. Each subjects' postural stability was quantified while performing simulated mining tasks both in static (in a stationary position i.e. not walking) and dynamic (i.e. while walking) conditions under low seam ceiling. The quantification of postural stability during static condition constituted exposure to individual and combined risk factors of 3 types of surfaces (firm-dry DCOF: 0.90, uneven-dry DCOF: 0.59 and firm slippery surfaces DCOF: 0.22); 2 types of environmental lighting (poor and glare); 2 types of postures (kneeling postures using 1 knee and 2 knees); 4 types of mining tasks (stationary, lifting buckets of bits, lifting cables and scaling). For the static condition all miners wore only one type of footwear (leather steel-toe boot). The quantification of postural stability during dynamic condition constituted the same risk factors as those used for static condition except for task type and footwear used. For the dynamic condition the footwear used were leather steel-toe boot and rubber steel-toe boot and task types were walking with and without weight (20 lbs).

The results from the proposed study has now provided critical data to enhance an existing statistical model originally developed by us with NIOSH sponsorship [1R01-OH 02794 "Role of Postural Balance in Industrial Falls" (26)] showing the relationship between postural instability and/or loss of balance and the independent variables characterizing the Environmental and Job-Task factors for task performance in an environment simulating underground mines. The enhancement of the model will add the effects of new (currently not available in the model) risk factors of restricted posture, glare, kneeling, task type and uneven/slippery surface which are typically found in low-seam underground mines. In future field studies, this statistical model can be used to help evaluate the propensity for postural instability and/or loss of balance by measuring, in a walk-through evaluation, existing risk factors at the mining worksite. A determination of which of the risk factors need to be corrected to reduce the propensity for postural

instability and/or loss of balance will then be possible. Availability of such models will have significant impact in identifying risk factors during job and workplace analysis of mining sites. Based on results from this study, improved work practices/training can now be developed to reduce the likelihood of workers' slips/falls while working in low seam mines. The results from this study can now be used to develop guidelines for mining workplace redesign to allow appropriate sufficient floor spacing so that workers can increase their base of support, minimizing the potential of postural instability. Results from this study can also be used to provide scientific data about postural instability under various combinations of workplace risk factors as input into the MSHA's human factors' training program software.

SIGNIFICANT FINDINGS

Based on analysis of postural stability associated with task performance under static conditions task type significantly affected all 10 outcome variables of the postural sway, postural stability (CP based) postural balance (CG based). Based on the results from these 10 variables the tasks of lifting of bits (7 variables out 10 ranked it most unstable), cable lifting (7 variables out of 10 ranked it second most unstable), scaling and stationary were ranked least to most stable as it relates to miners' postural balance, respectively. This finding is consistent with ranking of tasks producing the most to least numbers of observed slip events (during task performance) to be also lifting of bits (19.4% slips observed), cable lifting (18.9% slips), scaling (16.3% slips) and stationary tasks (4% slips), respectively. The rating of perceived exertion (RPE) and perceived sense of slip/fall (PSOS) were also significantly affected by the type of task performed. The miners reported increasing levels of perceived exertion as captured by the RPE scale ranging from least to the highest for tasks of stationary, lifting of bits, cable lifting and scaling respectively. On the other hand miners reported highest to least perception of slip while performing tasks of scaling, lifting of bits, lifting of cables and stationary, respectively. The type of knee posture used (1 knee vs. 2 knee) during above mentioned task performance was also significantly influencing miners' postural sway/stability as well as subjective perception of exertion and slips/falls. Based on all 10 variables of postural sway/stability one knee posture (7 out of 10 variables ranked it most unstable) was most unstable compared to the two-knee posture. A one-knee posture was rated higher in terms of both RPE and PSOS as compared to a two-knee posture, which is consistent with objective measures of postural sway and stability/balance. In other words PSOS was accurately rating the one knee posture to be more threatening to postural stability/balance than that with two knee posture. While consistency between subjective and objective measure supports the fact that miners were correctly judging the threat of instability associated with one-knee posture they were not successful in deploying appropriative and corrective postural responses to minimize slips during task performance with one-knee posture as this posture (as opposed to two-knee posture) produced the most numbers of slips. This may suggest to re-evaluate the task methods used and develop changes in work methods to minimize slips during certain task performance.

The working surface type significantly affected only 2 out of 3 CG based postural imbalance variables showing that firm-slippery surface was more threatening to postural balance than the other two working surfaces i.e. uneven-dry and firm-dry. The miners accurately reported the degree of slipperiness of three surfaces with the use of subjective scale of PSOS. The PSOS response implies that the body accurately perceived the threat to the postural balance due to changes in surfaces, which should have provided corrective postural muscle actions to actually reduce the postural sway responses in an effort to minimize postural instability. However, only excursion in AP direction was significantly reduced for the firm-slippery surface condition. Based on postural imbalance indices of CG based minimum IPSB and WRTI the firm-slippery surface produced poorer postural stability in spite of body's ability to correctly perceive the threat of the surface associated postural instability. This miss-match between perception and the objective measure of the postural instability provides evidence that under certain risk factors human body is not capable of deploying the necessary postural corrective muscle actions.

During performance of dynamic or gait task, the type of walking surface was significantly associated with 10 out of 12 gait outcome variables. The firm-dry surface followed the uneven-dry surface in terms of force, power or torque generated, with the firm-slippery surface eliciting the least force, power or torque. This was expected, as the firm-slippery surface does not provide the necessary foot-floor surface friction to allow development of adequate ground reaction forces and moments necessary for safe upright balance. Because of this, subjects' ability to maintain safe upright balance without slips/falls may be jeopardized while carrying out tasks on slippery surface. This is supported by the fact that firm-slippery surface produced the highest level of slip incidence (83% of trials produced slips) and fall incidence (8% of trials produced falls).

The type of surface significantly affected both the perceived exertion (RPE) and perceived sense of slip (PSOS) outcomes ($p<0.0001$). A firm-slippery surface was rated as producing 8.1% more exertion than a firm-dry surface and 5.2% more than an uneven-dry surface. The firm-slippery surface was rated 93.9% and 86.3% higher, in terms of PSOS, as compared to the firm-dry surface and uneven-dry surfaces, respectively.

Carrying a weight also significantly affected both RPE and PSOS ($p<0.0001$). Carrying a weight induced 20.5% greater RPE and 40.6% greater PSOS than not carrying a weight. This increased perceived level of exertion and slips during carrying weight was consistent with body's response to increase in gait associated changes in gait variables i.e. maximum braking force ($p<0.02$), contact time ($p<0.0001$), braking/propulsion power ($p<0.0006$), vertical power ($p<0.0001$) and maximum positive torque ($p<0.04$). Increases in these variables suggests that during carrying of weight the body's gait pattern changed to reflect cautionary motion requiring extra physical effort on the part of the subject as was demonstrated by increased value of RPE.

The type of surface was found to be significantly related to both slips ($p<0.0001$) and falls ($p<0.03$) during dynamic (i.e. gait) task performance. A slip was much more likely on the firm-slippery surface than on either the firm-dry surface (OR=50.0) or the uneven-dry surface (OR=25.0). Similarly, falls occurred much more often on a firm-slippery surface than either a firm-dry (OR=19.0) or uneven-dry (OR=17.5) surface. Carrying a weight was associated with an increased probability of slip ($p<0.004$, OR=2.0). Wearing a rubber boot lead to an increased probability of fall ($p<0.02$, OR=5.7).

SCIENTIFIC REPORT

A. BACKGROUND AND SIGNIFICANCE

Data reported by the NIOSH mining human factors group indicates that during 1983 to 1989, more than 9000 ergonomic hazards were identified at 144 underground mines (1). In another report Gallaghar et. al (2) indicates that manual task injuries are a major part of all accidents. Peter et. al (3) (1994) reports that "handling materials and slips or fall" accounted for over half of the serious injuries (defined as those classified as permanently disabling and those which caused more than 20 days of lost work) reported during the 1989 to 1991 period. During this period (1989-91) serious injuries associated with handling material and slips or falls accounted for 36.4% (highest) and 16.4% (second highest), respectively, of all serious injuries. Both handling materials and slip/fall-related injury rate increase as the mines get bigger. The rate (defined as per 200, 000 employee-hour of exposure) of injury increases over two fold (1.11 versus 0.47) at mines with over 100 employees compared to those at very small mines (employing <20 people). A similar trend was found for the injury rate associated with "handling materials".

The mining industry requires work in restricted postures in mines with low-ceiling heights (low-seam mines). These restricted postures require workers to exert higher muscle forces (4) and require higher energy consumption (5). Additionally, restricted posture limits the weight that can be safely handled by workers (6). Stooping or kneeling produces additional demand on visual, vestibular (due to tilted head, shoulder and abdomen), and proprioceptive (due to non-normal posture) systems and requires spatial adaptation for maintenance of balance while performing the task. Under these circumstances, the worker's ability to maintain safe upright balance during task performance may be jeopardized, resulting in near fall and/or fall related incidents. Significant research work has been carried out in the area of work physiology and biomechanics of low back injury associated with mining tasks in restricted postures (7). Gallagher et al.'s study (6) of back injury in mines implied that kneeling postures may decrease stability and balance, however no quantitative data were given. In summary, the literature is not comprehensive in the area of ergonomics of postural instability and potential loss of balance associated with mining tasks performed in restricted postures (kneeling and stooping) under individual and combined risk factors found in low seam mines. This is one of the major issues dealt with in this study.

Miners are exposed to a variety of risk factors, both individually and collectively, on a daily basis at their workplace. Some of these risk factors are: wet/muddy/slippery surface, uneven walking surfaces, restricted workspace, poor environmental lighting, limited ceiling height (in low seam mines), heavy lifting and high whole body vibration (8-9). Manual handling of materials in a restricted workplace require miners to assume postures, which may pose danger to his/her ability to maintain "safe" postural stability (i.e. without causing a fall or near fall incident to occur). This can be further explained as follows: The conditions which will allow "safe" postural stability during performance of manual material handling tasks (such as lifting) include: a firm foot placement and a big enough base of support (BOS) or stability boundary (BOS defined by the outer boundary of the feet during standing; during kneeling BOS is defined by the knee and toe placement) so that the body's center of gravity (CG) can stay inside the BOS thereby minimizing any potential loss of balance (10-11). In a workplace with restricted ceiling heights, such as those found in the underground low seam mines, the miners may not have the luxury to take an appropriate stepping action to increase their BOS during material handling task performance. Under these circumstances miners are forced to perform their tasks while being at the outer edge of their stability boundary. When the body's CG is at or near its outer edge of stability boundary during task performance, a small perturbation in body motion (such as a sudden move, shift of load being handled etc) and/or reduction in the COF value of the standing/walking surface, could easily jeopardize a miner's ability to maintain upright balance. Therefore, manual tasks such as lifting, thrusting action (which will increase the COF demand at the shoe/floor interface) with a Scaling Tool (Scaling Task) and/or walking in a stooped posture could place miners at a constant risk of loss of balance, which may result in a near fall and/or an actual fall event and possibly resulting in serious injuries. Manning et. al (12) reports risk of back injury during slips/falls. During unexpected events such as slips/falls or near falls may cause the trunk muscles to overcompensate thereby overload the spinal unit. Marras et.al (13) showed that during unexpected load handling situation the mean back muscle force levels were about 2.5 times higher than that measured for the expected loading condition. Therefore, postural instability associated with task performance in restricted posture under exposure to risk factors which may give rise to slips/falls, will have added implication of potential risk of low back injury. However, it is beyond the scope of the proposed study to actually measure back muscle loading under sudden unexpected loading, which has been already carried out by other investigators (13).

There are two kinds of tasks, which can place the human body at risk of slipping and falling. These are pseudo- dynamic tasks performed in a standing position (Static Tasks) and tasks performed while walking (Dynamic Tasks) on an uneven and/or slippery surface. The effect of these two types of tasks on the potential of postural instability, and loss of balance has been evaluated in previous studies carried out in our laboratory in an unrestricted ceiling height (10-11,14-16) but no data exists in the literature regarding similar work with restricted ceiling height. This forms the basis of one of the main foci of the proposed study.

Generally, before a fall incident occurs, the worker first experiences postural instability or propensity for postural instability, which in some cases may result into unrecoverable loss of balance. The ability to sustain upright balance requires continual input from several sensory systems. These include proprioceptors in the joints, pressure receptors in the soles of both feet, along with the visual and vestibular systems. Continuous regulation of balance results through patterns of neuromuscular coordination along many afferent and efferent pathways. Workplace risk factors such as environmental lighting, standing surface compliance and slipperiness, muscle fatigue, loss of peripheral vision and task type have been found to modify the effectiveness of the sensory system's functionality in the maintenance of postural stability of the worker (11,14,16-17).

Postural instability is generally assessed by measuring the movement patterns of the body's center of pressure (CP) while loss of balance is assessed by measuring the movement patterns of the body's CG in relation to subject's base of support (10-11, 18-19). Studies from our laboratory have shown that in a workplace with unrestricted ceiling, risk factors such as environmental lighting, surface slipperiness, surface compliance and task type have significant influence in modifying workers' postural stability (11, 14-15, 17). In a study with 52 industrial workers performing simulated industrial static tasks (14), it was found that of all risk factors (workload, task type, lighting peripheral vision, surface compliance, slippery surface of COF 0.3), the two most deleterious to postural stability were task-type and environmental lighting (14). In another study from our laboratory (15-17), the effect of static task type, three levels of slippery surfaces (COF: .35, .18 and .11), shoe wear (used-worn out or new) and environmental lighting on postural stability of 40 industrial workers was investigated. The results indicated that the three factors most strongly related to propensity of postural instability were task type, lighting and surface contamination or slipperiness. In another study, the effects of dynamic task type (walking on a straight path and a turning path) and two levels of surface slipperiness (COF: 0.67 and .11) on loss of balance in 10 industrial workers were investigated (11). This study developed seven biomechanical variables based on movement of whole body CG to quantitate the level of loss of balance associated with dynamic task performance on a slippery surface (11). However, no data exists regarding the effect of restricted posture on postural instability of workers performing static and dynamic tasks, when exposed to the individual and combined risk factors of_restricted ceiling height, uneven standing/walking surface, environmental lighting and slippery standing/walking surface. These are some of the critical issues, which were addressed in the study.

Illumination is a serious factor in underground mining. In order to increase the level of illumination in the underground mine, equipment designers inadvertently give rise to unnecessary glare in the environment which could cause safety hazard for both an equipment operator and the miners carrying out material handling tasks around the machines (20-21). While previous studies (14-16) have shown that environmental lighting has significant effects on postural stability, there exists no data regarding the role of glare in modifying postural stability. Physiologically speaking, visual cues in the environment are used as one of the critical afferents necessary for the maintenance of upright balance (22-24). It is reasonable to assume that in an environment with glare, the human eye will not be able to identify the appropriate vertical and horizontal cues as necessary afferents needed for safe upright postural balance maintenance. Preliminary studies provide some pilot data (25) regarding the effect of glare on postural balance. In this study, we investigated the effect of glare (in addition to other risk factors mentioned earlier) on the workers' ability to maintain upright balance.

A.1. Relevance and Significance to Workers' Health and Safety

The manual material handling tasks in underground low seam mines present a myriad of ergonomic risk factors, which place inordinate demands on miners' neuromuscular system. Material handling in restricted posture will cause potential of loss of stability/balance to increase; therefore, lifting task analysis should include information about postural stability/balance. Currently such information does not exist for material handling in a static stooped/kneeling posture and dynamic (gait) stooped posture. The proposed study will provide this type of information. This information could be used for task analysis of material handling in mine site.

Results obtained from the proposed study with miner worker subjects will provide the basis for future studies using a larger sample from the mining worker population. For example, all test conditions (encompassing risk factors such as, restricted work postures, task type, surface slipperiness, surface unevenness, and environmental lighting and glare) evaluated in the proposed study are rank-ordered for postural instability and/or loss of balance using established objective criteria described in Section C. Also, number of slips/falls experienced during the performance of simulated industrial tasks will allow us to determine the relationship between measures of postural instability and/or loss of balance and actual incidence of slips/falls in the simulated environment. These findings will provide the framework within which future mining worker-population-based prospective studies can be designed to address the following issues.

A. The results from the proposed study will help enhance an existing statistical model originally developed by us with NIOSH sponsorship [1R01-OH 02794 "Role of Postural Balance in Industrial Falls" (26)] showing the relationship between postural instability and/or loss of balance and the independent variables characterizing the Environmental and Job-Task factors for task performance in an environment simulating underground mines. The enhancement of the model will add the effects of new (currently not available in the model) risk factors of restricted posture, glare, kneeling, task type and uneven/slippery surface which are typically found in low-seam underground mines. In future field studies, this statistical model can be used to help evaluate the propensity for postural instability and/or loss of balance by measuring, in a walk-through evaluation, existing risk factors at the mining worksite. A determination of which of the risk factors need to be corrected to reduce the propensity for postural instability and/or loss of balance will then be possible. Availability of such models will have significant impact in identifying risk factors during job and workplace analysis of mining sites.

B. Based on results from the proposed study, improved work practices/training can be developed to reduce the likelihood of workers' slips/falls while working in low seam mines. The results from this study will also provide guidelines for mining workplace redesign to allow appropriate sufficient floor spacing so that workers can increase their base of support, minimizing the potential of postural instability. Results from this study can also be used to provide scientific data about postural instability under various combinations of workplace risk factors as input into the MSHA's training programs where softwares are being developed to include human factor's issue (27).

C. Data collected will fill the gap in information needed to develop guidelines for identifying and reducing risk factors which increase the slips/fall potential while working in a low seam underground mines.

B. SPECIFIC AIMS

1. To determine the postural imbalance, in terms of increased postural sway area and length and increased indices of postural instability and loss of balance (IPSB, SAR and WRTI), during task (static and dynamic) performance in restricted and/or low-ceiling height spaces requiring the worker to assume restricted awkward postures. Scaling and material handling types tasks (static and dynamic) were evaluated in this proposal.

2. To determine the influence of specific work-postures on the above relationship between postural imbalance and task (static and dynamic) performance in low-ceiling and/or restricted areas. Two restricted postures of kneeling (1-knee and 2-knee) and stooping, commonly adopted while working in low seam underground mine, were included in this study.

3. To determine the contribution of individual and combined risk factors on balance maintenance during task (static and dynamic) performance in low-ceiling and/or restricted areas. These risk factors include environmental lighting (poor < 0.2 footcandles; direct glare), and standing/kneeling surface conditions (firm, slippery and uneven) and type of footwear (steel-toed shoes and rubber boots).

4. To determine the effect of task performance in a stooped gait (dynamic task) on workers' ability to maintain upright balance under the individual and combined risk factors stated in 1 to 3.

C. METHODS

C.1. Miner-Subjects

For this study, a total of 25 subjects were tested. Subjects (both males and females) were recruited from the United Mine Workers of America, (UMWA) District 17, Local 2264, Pikeville, KY as well as mines in Middlesboro, KY. Initially Pikeville was chosen as a site for recruitment due to the close proximity to the University of Cincinnati, as well as the fact that several mines in the area had laid off workers. When recruitment began, however, miners in Pikeville were back to work and could not get leave to participate in the study. Therefore, another town was selected for recruitment: Middlesboro, KY. Miners in Middlesboro were laid off at the time of recruitment and were available to participate; however several had reservations coming to Cincinnati. It was determined by the research group to perform static balance testing only in Middlesboro (to gain trust and support) and then ask participants to complete the gait dynamic balance testing in Cincinnati at a later date. Some of the miners agreed to come to Cincinnati to complete both sections (balance and gait) of the testing during one visit. One miner who completed the static balance testing in Middlesboro refused to complete the gait dynamic balance testing in Cincinnati; this subjects' balance data was retained but was not used in the data analysis. Table 1 provides a description of the number of subjects tested in the laboratory (Cincinnati, OH) and in the field (Middlesboro, KY).

Table 1. Subjects tested per location of testing.

Location of Testing.	Static balance testing	Gait dynamic balance testing
Middlesboro, KY	8	0
Cincinnati, OH	18	25
Total	26*	25

*1 subject completed static balance testing in Middlesboro but did not complete gait dynamic balance testing in Cincinnati; this subjects' data was not used for data analysis

C.1.a. Health Screening of Subjects

Subjects interested in participating were mailed a health survey questionnaire (Appendix A) with a self-addressed stamped envelope. The questionnaire investigated thoroughly the potential of subjects' current or past exposure to different chemicals/industries/hobbies that have the potential to affect their central nervous system, hence their postural balance (e.g., solvents, lead, pesticides, paint removal, furniture finishing, working in smelter, dry cleaning, etc.). Subjects were also asked about current prescription and non-prescription medications. In addition subjects were asked about current or past respiratory, cardiovascular, neurological, and musculoskeletal symptoms. All returned questionnaires were reviewed; any subject indicating a problem in any of the areas list above was further interviewed over the phone to collect more information about his/her exposure and medical condition prior to being scheduled for a physical examination.

The following are the exclusion criteria based on the health survey questionnaire results:

1-Daily requirements of prescription medication which may act upon the Central Nervous System (CNS), e.g. Sedative-hypnotic, Anti-Depressants, Neuroleptics Anti-parkinsonian, Anti-psychotics, or Antihistaminics.

2-Significant history of dizziness and/or tremors

3-Alcoholism,

4-Vestibular, neurological, or cardiopulmonary disorders,

5-Diabetic symptoms,

6-Acute or chronic low-back or knee pain

C.1.b. Physical Examination

Those who met the inclusion criteria were scheduled for a physical examination in Middlesboro, KY. All physical examinations were performed by a registered Nurse Practioner from the Middlesboro area. In addition to the general medical examination, the following assessments were conducted:

1-Lower Limb Strength Testing: measured using the MicroFIT2 manual muscle-testing unit. Four muscle groups were tested; the quadriceps, hamstrings, ankle plantar flexors, and ankle dorsiflexors. The test was repeated 3 times for each muscle group and the results were averaged and reported in pounds (see Appendix B for datasheet and instructions).

2-Vision Testing: completed using a Snellen Chart (see Appendix C for datasheet and chart used).
3-Anthropometric measurements: individual body segment measurements (see Appendix D for datasheet)

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

The following table summarizes the conditions for the experiment. Each of these conditions is described fully in the following section.

Table 2. Independent variables.

Static Balance	**Ceiling:** 1.12 m
	Footwear: leather steel-toe boot
	Surface: firm-dry, uneven-dry, firm-slippery
	Lighting: poor, glare
	Tasks: stationary, lifting bucket of bits, lifting cable, scaling
	Posture: 1 knee, 2 knee
Gait Dynamic Balance	**Ceiling:** 1.12 m
	Footwear: leather steel-toe boot, rubber steel-toe boot
	Surface: firm-dry, uneven-dry, firm-slippery
	Lighting: poor, glare
	Tasks: carrying weight, no weight

C.2.a. Surface

Three surface conditions were used in this experiment: (1) firm-dry (which served as an ideal surface condition and as a baseline), (2) uneven-dry (which simulated the rocky surface of the mine) and (3) firm-slippery (which represented slippery conditions from contaminants such as water/mud in the mines).

C.2.a.1. Coefficient of Friction (COF) Measurement System

To determine the coefficient of friction (COF) generated by the different shoe-lubricant and floor slipperiness, a series of coefficient of friction (COF) tests was conducted. Both static and dynamic COF between a new shoe and testing surfaces (firm dry and firm slippery aluminum plates and irregular surface) that will be mounted to a force platform were obtained using an existing computerized tribology set-up. The set-up includes a computer-controlled microstepping motor (Compumotor s83-135, Parker Hannifin Corporation, Rohnert Park, CA), a gear box used to pull the shoe at desired velocity, an indexer (Model PC21, Parker Hannifin Corporation) used to receive information from the supplied software to generate motion commands to signal to motor axis, and a force platform (Model 3371, OR6-5-1000, AMTI, MA). Forces in three directions (x, y, z) are measured by the force platform and used for COF calculation. The methodology of calculating COF is described in detail in our previous studies (NIOSH grant R01-OH3079-02, R01-OH2794-02 and 16). Static and mean dynamic COF over a sample period of approximately one second were calculated with a custom program developed in our laboratory. Description of the current program and the protocol for the COF testing is shown in Appendix E. The calculated static and mean dynamic COF were written down from the computer screen for further statistical analyses. A typical COF plot is presented in Figure 1.

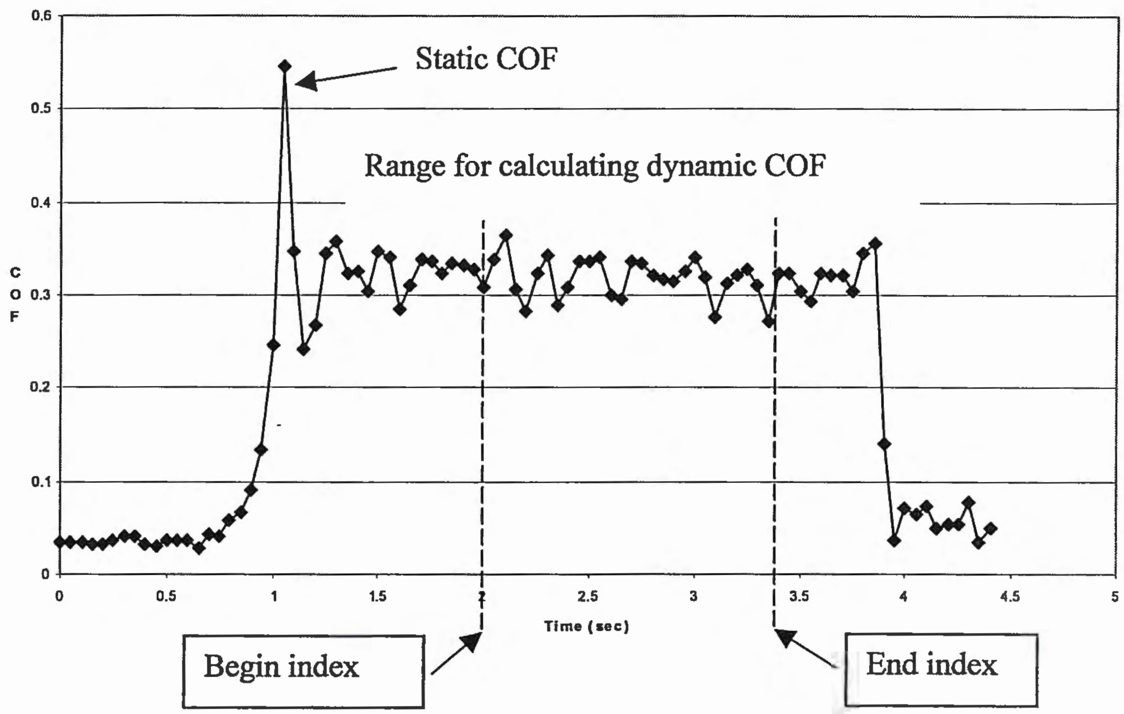


Figure 1. A typical COF plot for slippery surface

C.2.a.2. Selection of Plates and Lubricants for Creating Slipperiness Of Desired COF For Static and Dynamic (gait) Balance Testing

In order to determine the most desirable and practical method for experiment set-up, the shoe-floor COF was tested in various conditions where various amounts of mineral oil were applied to a coarse aluminum (Al) plate. Aluminum plates (#6061-T6, Brinell Hardness 85) are placed on top of the force platform, connected with a magnet, so that the contaminants are not placed directly on the force platform. Two types of shoes (leather steel-toe boots (L), model #1778, Carolina Shoe Co. and rubber steel-toe boots (R), LaCrosse Rainfair Safety Products) were used for the COF testing. The COF results for final test conditions are summarized in Table 3. Based on the COF results, mineral oil was selected as the medium for creating a slippery surface with desired COF between the shoe and the floor.

Table 3. Summary of the COF results for final test conditions. (N=5)

Test Condition	Lubricant	Amount of Lubricant	Surface	Dynamic COF for Balance Evaluation (mean±SD)	Static COF for Balance Evaluation (mean±SD)
Uneven Dry	None	0 ml	Polymer (for both small and large)	0.59 ± 0.12 (L)* 0.90 ± 0.12 (R)*	2.12 ± 0.97 (L)* 2.22 ± 0.30 (R)*
Firm Dry	None	0 ml	Bead blasted aluminum plate (Small)	0.90 ± 0.07 (L)* 1.00 ± 0.13 (R)*	0.94 ± 0.12 (L)* 0.97 ± 0.14 (R)*
			Bead blasted aluminum plate (Large)	0.95 ± 0.06 (L)* 1.20 ± 0.31 (R)*	1.07 ± 0.06 (L)* 1.62 ± 0.42 (R)*
Firm Slippery	Mineral Oil	10 ml	Coarse aluminum plate (Small)	0.23 ± 0.01 (L)* 0.15 ± 0.02 (R)*	0.47 ± 0.08 (L)* 0.34 ± 0.06 (R)*
		20 ml	Coarse aluminum plate (Large)	0.22 ± 0.02 (L)* 0.16 ± 0.02 (R)*	0.55 ± 0.13 (L)* 0.34 ± 0.12 (R)*

*(L)=leather steel-toe boots
(R)=rubber steel-toe boots

Testing of Reproducibility of the COF Values across Trials

In slippery condition trials (balance and gait), the subject kneels/steps on a force plate to test his/her balance in different conditions with two types of shoes. After the balance test, the subject steps off the plate and sits on a chair to rest. To avoid contaminating the test area, a piece of clean paper is placed by the chair for the subject to rest his/her feet. A special mat was used during gait dynamic balance testing to protect the test area when subjects were walking past the plate with their shoes contaminated with the lubricant. Since the paper/mat may absorb some of the lubricant that came into contact with the shoe surface, COF testing was carried out to test if the COF values remained consistent between trials. To simulate the trial condition, the tester wore the shoe after each COF test trial and shifted his foot on a piece of clean paper to simulate the feet movement of a subject getting off the plate to rest. Then the tester redistributed the lubricant on the plate with a latex glove to make a uniform surface and placed the shoe on the plate for the second COF test trial. The same test protocol was followed for the remaining 19 trials. One shoe type and plate size was tested. Table 4 shows the results from the COF testing.

The coefficients of variations (CV) of the dynamic COF (DCOF) results for twenty trials were within an acceptable range (6.4% to 17.6%).

Table 4. Results from Testing the Variation of the SCOF and DCOF over Twenty Trials.

Test Condition	Lubricant	Amount of Lubricant	Surface	DCOF ± SD (%CV)	SCOF ± SD (%CV)
Firm Slippery	Mineral Oil	20 ml	Coarse aluminum plate (Large)	0.22 ± 0.01 (6.42%)	0.51 ± 0.09 (17.6%)

C.2.a.3. Testing Of Reproducibility Of The COF Values Throughout Data Collection Period

The same set of shoes was used for the entire study period (3-4 years). For both balance and dynamic balance tests, to characterize the changes in sole properties due to repeated use of the shoes, COF testing was repeated after half the subjects were tested and finally after all subjects' testing was completed. The changes in the shoe COF are summarized in Tables 5 and 6. The changes in the DCOF did not follow a particular pattern over time.

Table 5. Summary of the DCOF Changes during the Study Period.

Test Condition	Lubricant	Amount of Lubricant	Surface	Start of Study DCOF ± SD	End of Study DCOF ± SD
Uneven Dry	None	0 ml	Polymer (for both small and large)	0.59 ± 0.12 (L)* 0.90 ± 0.12 (R)*	0.78 ± 0.04 (L)* 0.97 ± 0.06 (R)*
Firm Dry	None	0 ml	Bead blasted aluminum plate (Small)	0.90 ± 0.07 (L)* 1.00 ± 0.13 (R)*	1.10 ± 0.04 (L)* 1.12 ± 0.05 (R)*
			Bead blasted aluminum plate (Large)	0.95 ± 0.06 (L)* 1.20 ± 0.31 (R)*	1.03 ± 0.04 (L)* 1.16 ± 0.04 (R)*
Firm Slippery	Mineral Oil	10 ml	Coarse aluminum plate (Small)	0.23 ± 0.01 (L)* 0.15 ± 0.02 (R)*	0.27 ± 0.02 (L)* 0.18 ± 0.02 (R)*
		20 ml	Coarse aluminum plate (Large)	0.22 ± 0.02 (L)* 0.16 ± 0.02 (R)*	0.21 ± 0.02 (L)* 0.15 ± 0.05 (R)*

*(L)=leather steel-toe boots
(R)=rubber steel-toe boots

Table 6. Summary of the SCOF Changes during the Study Period.

Test Condition	Lubricant	Amount of Lubricant	Surface	Start of Study SCOF ± SD	End of Study SCOF ± SD
Uneven Dry	None	0 ml	Polymer (for both small and large)	2.12 ± 0.97 (L)* 2.22 ± 0.30 (R)*	0.89 ± 0.10 (L)* 1.28 ± 0.29 (R)*
Firm Dry	None	0 ml	Bead blasted aluminum plate (Small)	0.94 ± 0.12 (L)* 0.97 ± 0.14 (R)*	1.15 ± 0.13 (L)* 1.12 ± 0.16 (R)*
			Bead blasted aluminum plate (Large)	1.07 ± 0.06 (L)* 1.62 ± 0.42 (R)*	1.00 ± 0.06 (L)* 1.20 ± 0.07 (R)*
Firm Slippery	Mineral Oil	10 ml	Coarse aluminum plate (Small)	0.47 ± 0.08 (L)* 0.34 ± 0.06 (R)*	0.43 ± 0.06 (L)* 0.29 ± 0.06 (R)*
		20 ml	Coarse aluminum plate (Large)	0.55 ± 0.13 (L)* 0.34 ± 0.12 (R)*	0.37 ± 0.08 (L)* 0.31 ± 0.10 (R)*

*(L)=leather steel-toe boots
(R)=rubber steel-toe boots

C.2.b. Ceiling Height

All testing was completed with a restricted ceiling height of 1.12m (or 44 inches). For static balance testing a frame with chicken wire was placed at 1.12m on top of the prying structure to simulate a ceiling (see figure 2). For the gait dynamic balance testing two ropes were placed at 1.12 m that spanned the walking distance. The subject was asked to squat below the ropes before beginning to walk and remain low throughout the trial (see figure 7). An observer monitored the subject to stay low throughout the trial to ensure they stayed below 1.12m.

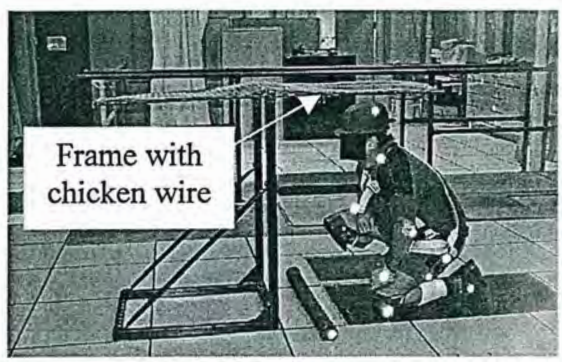


Figure 2. The simulated ceiling at 1.12 meters for static balance testing.

C.2.c. Footwear

For static balance testing, only one boot type was investigated since the subjects were on their knees and the boot had minimal contact with the surface. The leather steel-toe boots, model #1778, Carolina Shoe Co., were used for static balance testing. For gait dynamic balance testing both the leather boots (described above) and rubber steel-toe boots, LaCrosse Rainfair Safety Products, were used.

C.2.d. Environmental lighting

Two lighting conditions were used for testing: poor lighting (<2 foot candles) and glare lighting. Previously, good lighting was to be used, but good lighting (30-74 foot candles) is not commonly found in underground mines so it was eliminated. The poor lighting condition was to represent the miners working from their headlamps and lighting from equipment. We attempted to use the light from the headlamps for this condition, but the light source was a problem for digitizing, therefore ambient lighting was adjusted to create <2 footcandles. To create the glare lighting conditions, a flashlight (Mag-Lite) was held by the subject assistant such that the light is pointed at the face of the subject. The flashlight was used without any ambient lighting for the glare condition. See Figure 3 for the set up of the glare conditions for static balance testing; for gait dynamic balance testing the subject assistant held the light in the same location. Table 7 provides readings from simulated glare lighting conditions, readings were made with the light meter positioned directly towards the flashlight at 3 locations: eye level, right cheek and left cheek.

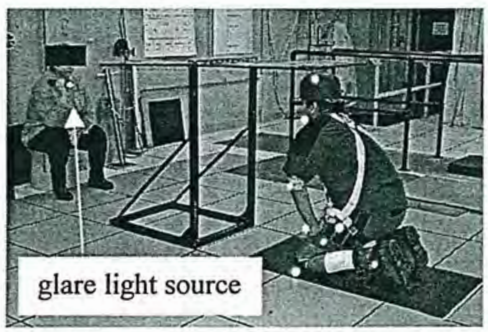


Figure 3. Glare lighting setup for static balance testing

Table 7. Simulated glare lighting readings.

Eye Level (fc)	Right Cheek (fc)	Left Cheek (fc)
8.5	4.0	5.0

C.2.e. Tasks for static balance testing

The following tasks were completed for the static balance testing: stationary, lifting a bucket of bits, lifting a cable, and scaling. We decided to use two common lifting tasks that are performed in mines. All static balance tasks were carried out on the large platform (see section C.4.a). The subject kneeled on one knee or two knees for the static balance testing. The one-knee posture was standardized with the left knee down. See figure 4 for the one-knee posture and figure 5 for the two-knee posture. The following describes the tasks in detail.

C.2.e.1. Stationary

For this task, the subject knelt below the restricted ceiling, relaxed with their wrists resting on each respective thigh for 30 seconds.

C.2.e.2. Lifting a bucket of bits

Mining bits are attached to a ripper head on a continuous miner (a piece of equipment used to mine), which mines the coal. These bits become worn and are replaced on a regular basis. The bit replacements come in a bucket with approximately 25 bits in it. The bucket used in the experiment had a diameter of 7.25 inches, is 8.8 inches tall and weighed 16.3 lbs. See Appendix F for the calculation of the maximum weight limit for this task. In the mine, the worker would asymmetrically lift the bucket from the ground up to the continuous miner. After the bits are replaced, the used bits are placed into the same bucket and lifted down from the continuous miner. For our simulation, the bucket was lifted from the ground on the left side of the subject up to a 34" shelf on the right side of the subject and returned to the ground. A voice command to begin the lift was given 8 seconds into the 30 second trial. The subject began the trial kneeling in a relaxed position as in a stationary trial. On a voice command, the subject began the lift cycle. See figure 4 for pictures of this task.

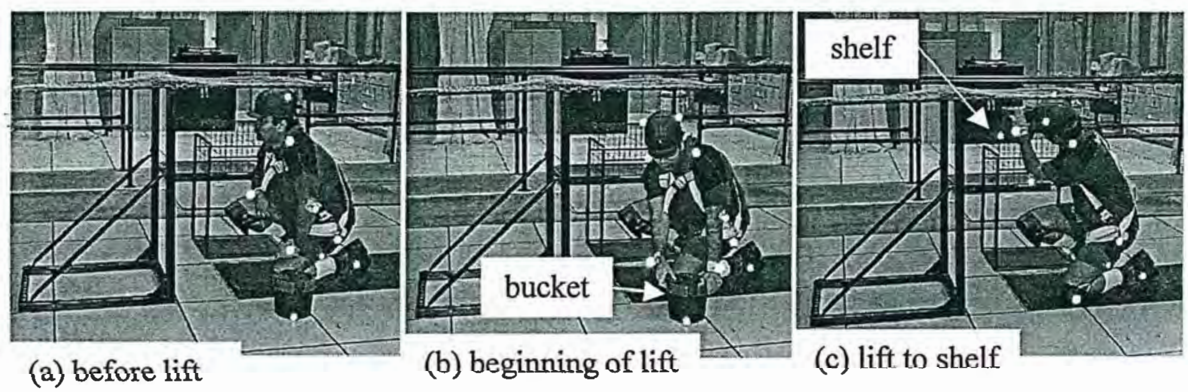
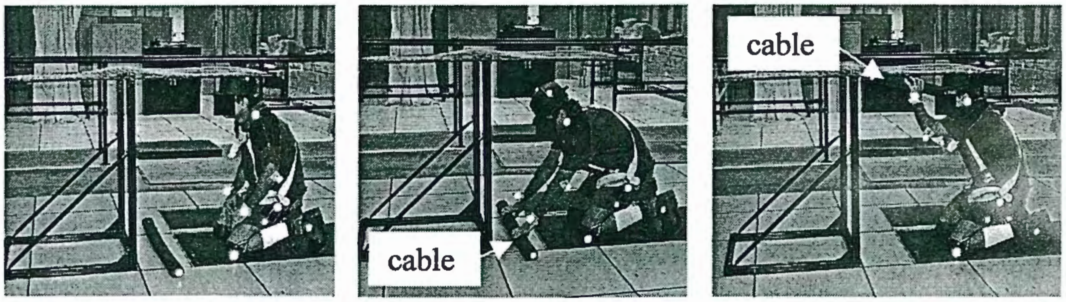


Figure 4. Lifting bucket of bits task in one knee posture.

C.2.e.3. Cable lifting

Electrical and water cabling is used throughout the mine. These cables are suspended from the ceiling using hanging devices (either clamps or hooks) attached to roof bolts. As equipment and supplies move throughout the mine, these cables must be moved accordingly. To simulate the task of securing the cable, the subject lifted a section of "cable" from the floor level in front of the force platform, up to the false ceiling then replaced the cable to the starting position. The cable was a rubber hose 45.5 inches long with a 2.5-inch diameter, weighing 16.3 lbs. See Appendix G for the calculation for a safe weight limit for this task. The subject began the lift on a voice command 8 s. into the 30 s. trials. The subject began the trial kneeling in a relaxed position as in the stationary trial. See Figure 5 for pictures of this task.

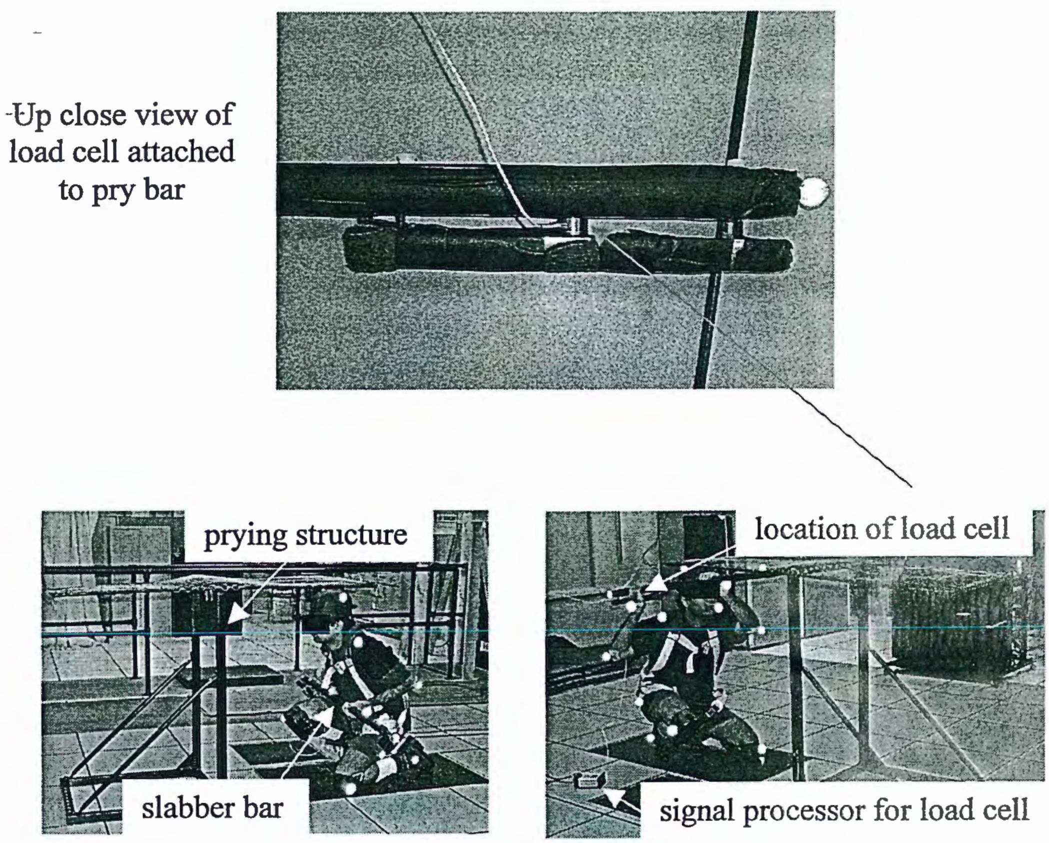


(a) before lift (b) beginning of lift (c) cable lifted to "ceiling"

Figure 5. Lifting cable task in the 2 knee posture.

C.2.e.4. Scaling

Scaling is a task where the miner uses a slabber bar to pry coal from the ceiling surface manually. To simulate the scaling task, a slabber bar was modified to attach a load cell to measure the force used to pry. The subject began the trial kneeling with the slabber bar (weight = 4 kg) in their hands; on a voice command (8 s. into the 30 s. trial) raised the bar and inserted it into position A marked on the scaling structure. The subject "pried" there once and moved the bar to position B and "pried" once there. After the second "pry", the subject returned the bar to the starting position for the remainder of the 30-second trial. See figure 6 for pictures of this task.



(a) before prying (b) prying

Figure 6. Scaling task in the 1 knee posture.

C.2.f. Tasks for Gait dynamic balance testing

Two tasks were completed for the gait dynamic balance testing carrying a weight and no weight.

C.2.f.1. Carrying a weight

For the Dynamic balance test, one task condition was the subject carrying a 14.5 kg (20 lbs) bag of rice of their back, supported by their left arm (see figure 7). The bag of rice was used to simulate a manual material-handling task common in mines, carrying bags of rock dust. The gait portion of the testing was completed with and without the weight.

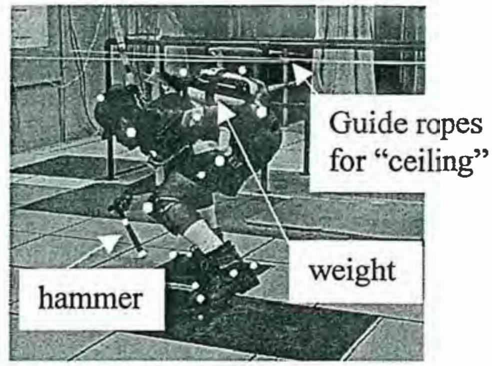


Figure 7. Gait trial with weight.

C.3. Study Facility and Testing Equipment

The layout for the lab testing area with the camera positions can be seen in figure 8. Figure 9 provides the coordinate systems used for the force plate and camera systems. The vertical + Z for the force plate was perpendicular (i.e. to the X-Y plane) and into the force plate (i.e. into the X-Y plane). The vertical +Z for the camera or kinematic coordinate was perpendicular (i.e. to the X-Y plane) and facing away from the force plate (i.e. away from the X-Y plane).

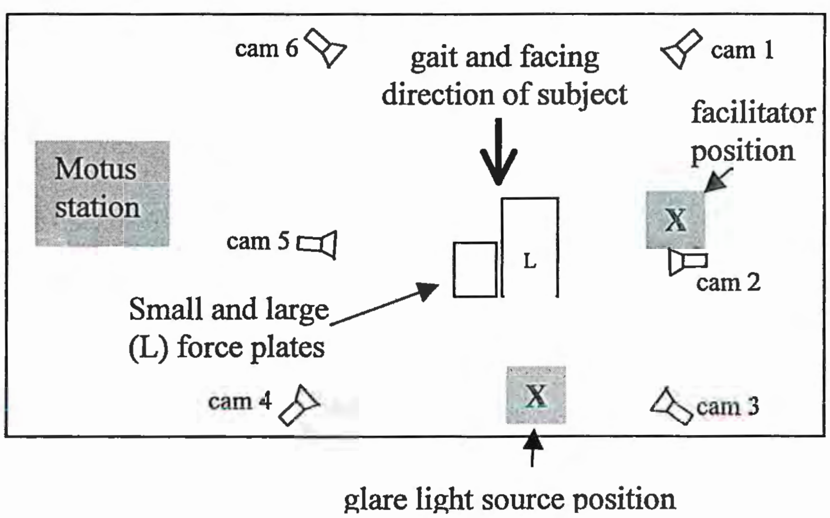


Figure 8. Testing area layout.

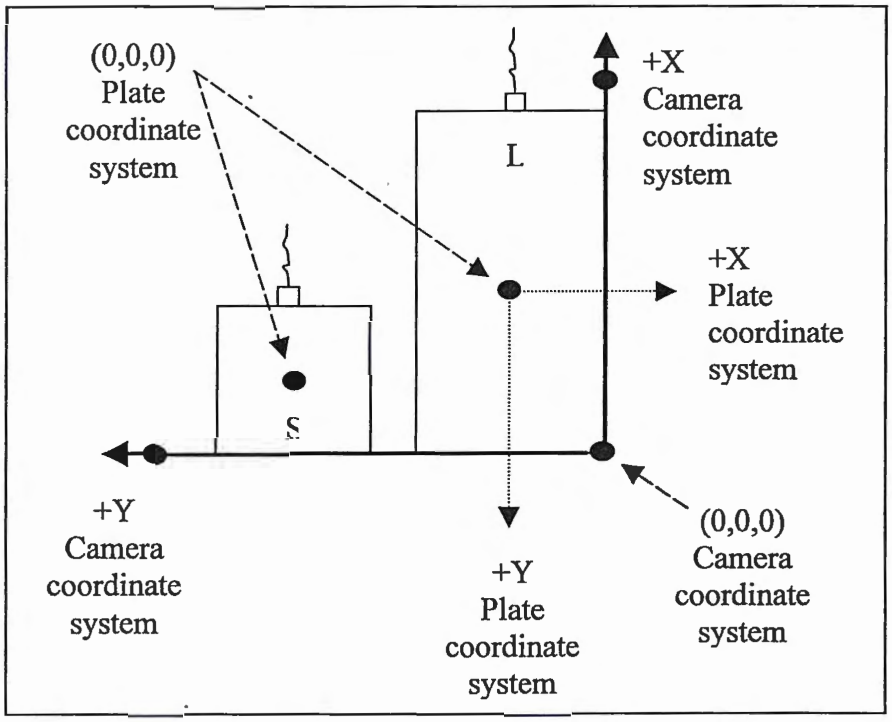


Figure 9. Camera and Force plate Coordinate Systems

C.3.a. Uneven Surface

To create an artificial surface that mimicked a mine floor surface, but was durable and washable, a local business that creates movie set designs was employed. Coal was laid across a flat surface to create the positive form. A negative mold was then made from synthetic cast (Synair Por A Mold S555) to be used as the mother mold. A prototype of 1' by 1' was poured using a polymer (Replicast 112, PTM&W Industries Inc., Santa Fe Springs, California). The prototype was shown to Mr. William Chapman, President of the United Mine Workers Association (UMWA) Local 7093 in Pikeville, Kentucky. He agreed that the surface was an appropriate replica of a typical mine floor. After confirming the prototype was appropriate, a total of 48 surfaces were poured to make 2 sets of surfaces, one for the dry condition and one for the slippery condition. Eight of the 1' x 1' surfaces were cut appropriately to fit the smaller force plate (measuring 18.25" x 20") for each condition. The surfaces were placed before and after the force plate for gait dynamic balance testing to allow for an even walking. A picture of the surfaces is shown in figure 10.

C.3.b. Mining Equipment

It was important to simulate the amount of weight the miners wear on their tool belts and the type of equipment used in an ordinary workday. For that reason we consulted with Mr. William Chapman, UMWA and Mr. Mark Bushnell, Kentucky Mine Supply, Harlan, Kentucky to determine which items were commonly used. Table 8 is a list of items acquired and used during testing.

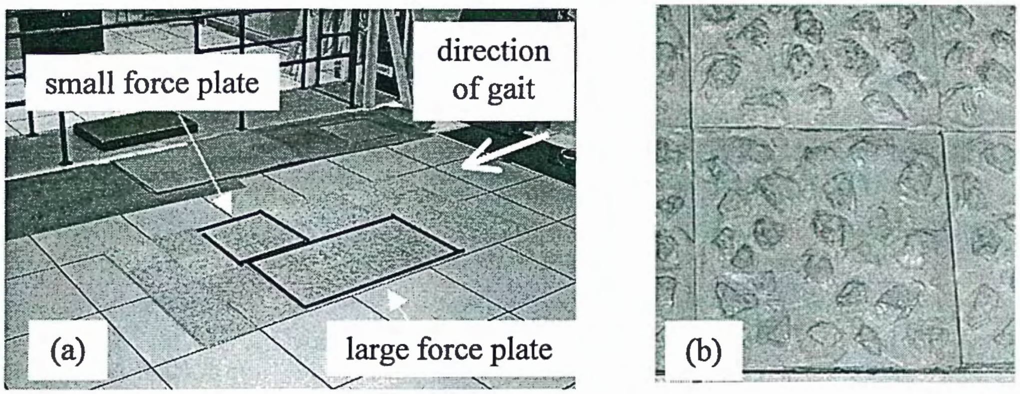


Figure 10. Uneven surface (a) set up for gait dynamic balance testing (b)

C.4. Instrumentation and Measurements
C.4.a. Kinetic measurements

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 platform has a 2' by 4' surface (model LG6-4-1000, serial # 3891) that is large enough for a person to squat and/or kneel on. The other platform was 18.25" by 20" (model OR6-7-1000, serial # 4134) and placed beside the larger one to accommodate gait dynamic balance testing. Two plates were required to achieve one heel strike per plate during the gait cycles.

Table 8. Mining equipment acquired and used during testing.

Item	Purpose	Company	Weight
4 ft slabber bar with steel tip	used for scaling task	Rock Tools, Salt Lake City, UT	4.0 kg
Fab-plus Knee Pads	worn for testing	Barwalt Co., Post Falls, ID	0.9 kg
Miners Cap MSA type I	worn for testing	Kentucky Mining Supply, Harlan, KY	0.5 kg
Prospectors Pick (hammer)	used for gait dynamic balance testing	Kentucky Mining Supply, Harlan, KY	0.7 kg
Nylon miners belt	worn for testing (S, M, L, XL and XXL sizes)	Kentucky Mining Supply, Harlan, KY	5.4 kg* (with weights)
Steel-toe waterproof boots	worn for balance and gait dynamic balance testing	Carolina Shoe Co, Berkshire Hathaway, Inc, Omaha, NE	2.2 kg (size 12)
Rubber boots with steel midsole and toe	worn for gait dynamic balance testing	LaCrosse Rainfair Safety Products, Portland, OR	5.6 kg (size 12)

* The miners' belt was modified with weights to simulate the approximate weight of a self-contained rescuer (model # Sr-100) and Koehler Wheat Light (model # 5000 series with battery un2800). The rescuer and light has weights of 2.9 kg and 2.4 kg, respectively.

In the laboratory force platforms were mounted such that the top of the platform was flush with the lab floor. Installation instructions from AMTI were followed. Each force platform was attached to a mounting fixture using bolts. The mounting fixtures (AMTI models SMF-2A for the LG6 and SMF-1A for the OR6) were made of 1" aluminum. The mounting fixtures were then attached with epoxy (Oxybond 116T2, Resin Technology Group LLC.) to concrete blocks that were poured to the required height to make the force platform with the magnet flush with the raised floor. In the field for balance data collection, only the large force platform was used. A structure was created that provided a solid surface around the platform. The location chosen to place the platform in the field was a flat, even, solid surface because the concrete blocks could not be moved to the field-testing location.

The surfaces (firm and uneven) were placed on top of the force platforms and the surrounding area. A self-adhesive magnet (flexible magnetic sheet #8621, 0.06"x24", Magnet Sales and Manufacturing, Culver City, CA) was affixed to the top of the force platforms for attachment of the various surfaces.

The signals from the force plates were each 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 static balance testing and 1050 Hz for the dynamic balance test. In the laboratory the signals coming out of the amplifier were then delivered to an IBM compatible, Pentium computer using A/D board and Peak™ Performance Motus Software-version 6.1.11 (Peak Performance Technologies Inc., Englewood, CO) for data collection. In the field signals coming out of the amplifier were delivered to an IBM compatible computer using Posture 6.0 software for data collection. The data collection frequency was set at 60 Hz and duration of 30 seconds (1800 data points) for static balance testing and at 600 Hz and duration of 8 seconds for gait dynamic balance testing. Collected data was further processed using KineLysis version 3.1.9 (all Rights Reserved, University of Cincinnati) 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. Kinematic Measurements

The real time video digitization system used was the Peak Motus system. This system consists of the following components:

(1) Peak Motus-configured computer with Peak Motus 2000 Trial Design and Display Core, Peak Motus 2000 3D Real Time Coordinate Acquisition system and the Peak Motus 2000 3D Calculations Module (version 6.1.11)
(9) 60Hz Shuttered Cameras: Phillips LTC 0500/60 NTSC (Serial numbers and focal lengths: Camera #1: 001826, 8.5mm; Camera #2: 001903, 6mm; Camera #3: 003451, 8.5mm; Camera #4: 003467, 8.5mm; Camera #5: 003470, 6mm; Camera #6: 003471, 8.5mm; Camera #7: 005394, 8.5mm; Camera #8: 006457, 8.5mm; Camera #9: 010285, 8.5mm and Camera #10: 010638, 6mm). Each camera is linearized by Peak and has a fixed focal length.
(6) Infrared lights and brackets

To collect data with this system, templates were created that include the cameras and calibration, spatial model (see section C.4.b.1. and C.4.b.2. for marker systems used) and analog setup. Complete descriptions of these templates are shown in Appendix H.

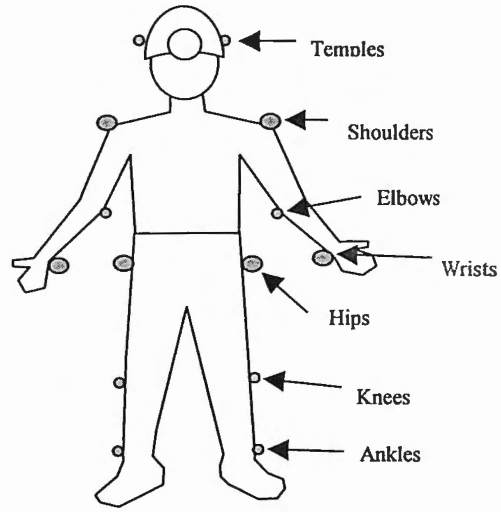


Figure 11. Marker system for balance testing.

C.4.b.1. Static Balance Marker System

The spatial model consists of 14 markers on the body, and 15-19 virtual points (4 on the force plate, 6 for the feet, 4 for the ceiling and 1 or 3 for the center of mass - this depends of if the task requires an object), and 2 markers on the item (again, if the task requires an object). The markers on the body include right and left ankle, knee, hip, shoulder, temporal, elbow and wrist. See Figure 11 for the balance marker system.

The virtual points for all balance trials were created using the Peak Motus system, not physical marker viewed by the cameras and include: Body center of mass, upper left of the large plate, lower left of the large plate, lower right of the large plate, upper right of the large plate, upper right ceiling, upper left ceiling, lower right ceiling and lower left ceiling. The additional virtual points for the trials with an object: center of mass of object (bucket of bits, cable or slabber bar) and the center of mass of body and object together. Due to difficulty digitizing the feet markers in Motus, the feet markers were eliminated. An estimation of their location was made by using measurements taken from the ankle marker on the shoe to the respective points (heel, 1st MTP and 5th MTP) on the shoe. These measurements were used in equations to create virtual points for these markers.

C.4.b.2. Gait Dynamic Balance Marker System

The spatial model consists of 36 points including 21 markers on the body, 2 markers on the hammer and 13 virtual points. The 21 body markers include right and left 1st MTP, 5th MTP, heel, ankle, knee, hip, shoulder, temporal, elbow and wrist. A left thigh reference marker is used to facilitate the auto path identify function. In addition, there are markers placed on the top and bottom of the hammer and on the weight (for the carrying weight trials only). See Figure 12 for the Gait Marker System.

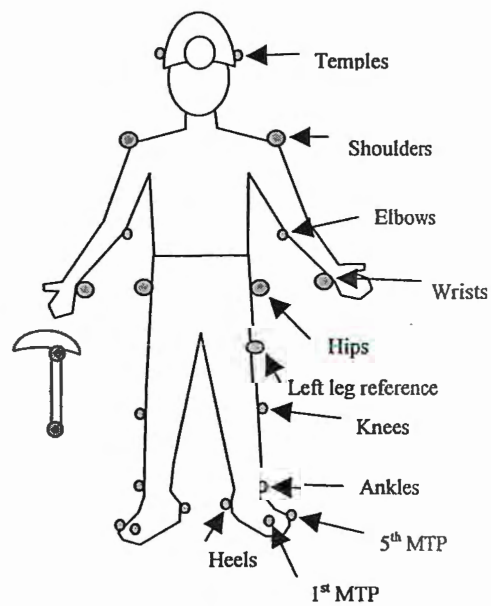


Figure 12. Marker system for Gait dynamic balance

The virtual points (again, created using the Peak Motus system) used in both gait trials included: body center of mass, upper left of the large plate, lower left of the large plate, lower right of the large plate, upper right of the large plate, upper left of the small plate, lower left of the small plate, lower right of the small plate, upper right of the small plate, upper right ceiling, upper left ceiling, lower right ceiling and lower left ceiling. The virtual points used in the weight trial (only) included: center of mass of the weight and the center of mass of body with the weight.

C.4.b.3. Center of Mass (COM) Setup

To appropriately add weight to the mining belt worn by subjects, it was assumed Miners would at least carry an emergency self-rescue breather and a large battery for the headlamp on their belts during all tasks (for both balance and gait trials). The belt with the self-rescue and lamp battery weighed 5.4 kg. This additional 5.4 kg load was distributed along the trunk and was accounted for in the kinematic spatial model. Using standard anthropometric data (Winter, 1990, see table 9), the additional load was added to the trunk segment of our model and each body segment was recalculated to reflect the additional weight and its segmental distribution. The static balance trials added the feet mass to the shank since feet were not included in the spatial model and are shown in Table 10. The gait segment mass percentage is shown in Table 11. Peak Motus software (version 6.1.11) allowed for the recalculation of segmental mass calculation for COM by allowing the user to modify the values for segment ratios; as well as add and/or delete segments.

Table 9. Segmental mass calculations for standard male (Winter D.A: The biomechanics and motor control of human gait, New York: John Wiley and Sons, Inc., 1987).

Segment	Segment mass ratio	Total mass ratio (includes left and right)	Total distribution of mass based on standard 56.7 kg model (includes left and right)
Forearm & hand	0.022	0.044	2.5 kg
Upper arm	0.028	0.056	3.2 kg
Foot	0.0145	0.029	1.6 kg
Shank	0.0465	0.093	5.3 kg
Thigh	0.100	0.200	11.3 kg
Trunk	0.497	0.497	28.2 kg
Head & neck	0.081	0.081	4.6 kg

Table 10. Segmental mass calculations for mining tasks with additional equipment weight (5.4 kg) added on belt for the Static Balance trials.

Segment	New mass based on standard 56.7kg model with additional 5.4 kg at trunk	% mass with additional 5.4 kg added to trunk (includes left & right)	New segmental % mass with additional 5.4 kg added to trunk
Forearm & hand	No change	4.0	2.0
Upper arm	No change	5.2	2.6
Shank +Foot	No change	11.2	5.6
Thigh	No change	18.0	9.0
Trunk	33.6 kg	54.2	54.2
Head & neck	No change	7.4	7.4

Table 11. Segmental mass calculations for mining tasks with additional equipment weight (5.4 kg) added on belt for the Gait Dynamic Balance trials.

Segment	New mass based on standard 56.7kg model with additional 5.4 kg at trunk	% mass with additional 5.4 kg added to trunk (includes left & right)	New segmental % mass with additional 5.4 kg added to trunk
Forearm & hand	No change	4.0	2.0
Upper arm	No change	5.2	2.6
Foot	No change	2.6	1.3
Shank	No change	8.6	4.3
Thigh	No change	18.0	9.0
Trunk	33.6 kg	54.2	54.2
Head & neck	No change	7.4	7.4

C.4.b.4. Center of Gravity (CG) Selector

Two trials (lifting bucket of bits and lifting cable) required the subject to begin the trial in a relaxed position and then lift an object. Since these objects were not included in the Center of Gravity for the subject their location and weight were determined using the Peak Motus system (version 6.1.11). The Center of Gravity during these trials had to be adjusted for the additional weight added to the subject during the lift. The Motus system was programmed to calculate both the Center of Gravity of the subject, as well as the Center of Gravity of the subject and the object they picked up. A program was then developed that used the Center of Gravity of the subject only when there was no weight in their hand, and then switch to the Center of Gravity of the subject and the object once the lift was initiated. When the lift was complete and the subject placed the object back on the ground, the Center of Gravity of the subject only was once again used. This program was used in calculating the IPSB variables.

C.4.b.5. Base of Support (BOS) Estimate for Static balance testing

The static balance testing was done in two postures: 1) one knee kneel (left knee down, right knee up) and 2) two-knee kneel. The BOS changed depending on whether the one-knee or two-knee posture was used. The following figures 12 and 13 show the two BOS for the two postures.

Figure 13. One-knee kneel stick figure (3 BOS markers):

A= right ankle
B= right knee
C= left ankle

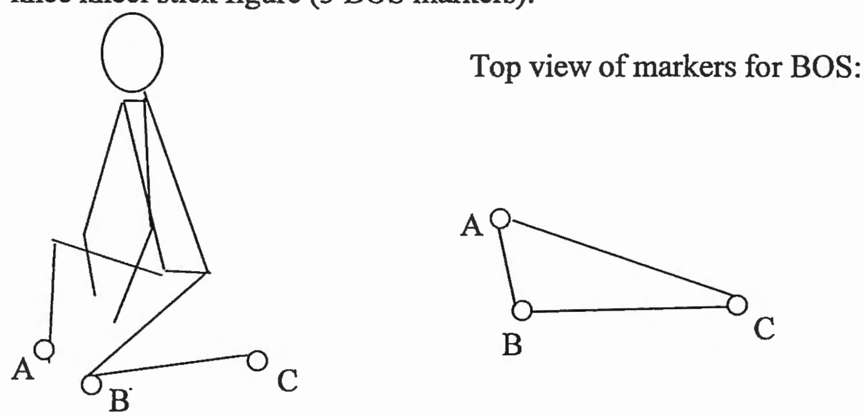
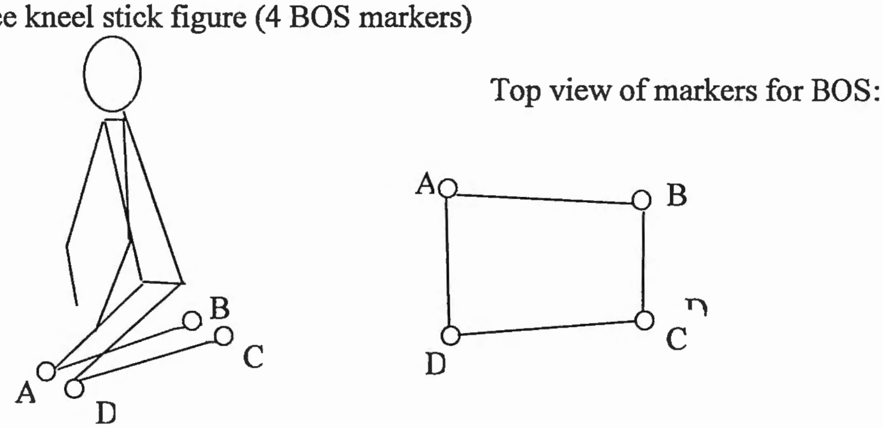


Figure 14. Two-knee kneel stick figure (4 BOS markers)

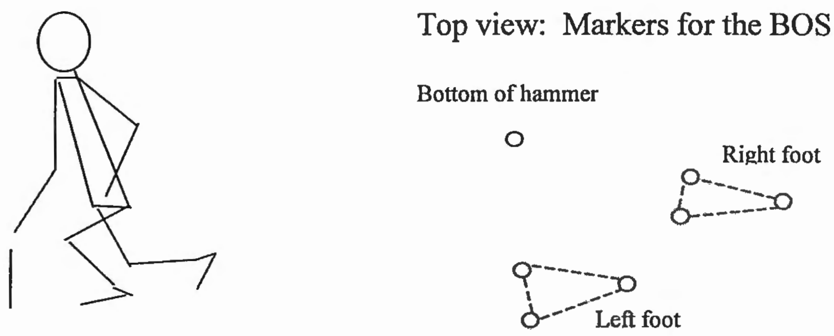
A= right knee
B= right ankle
C= left ankle
D= left knee



C.4.b.6. Base of Support (BOS) Estimate for Gait dynamic balance testing:

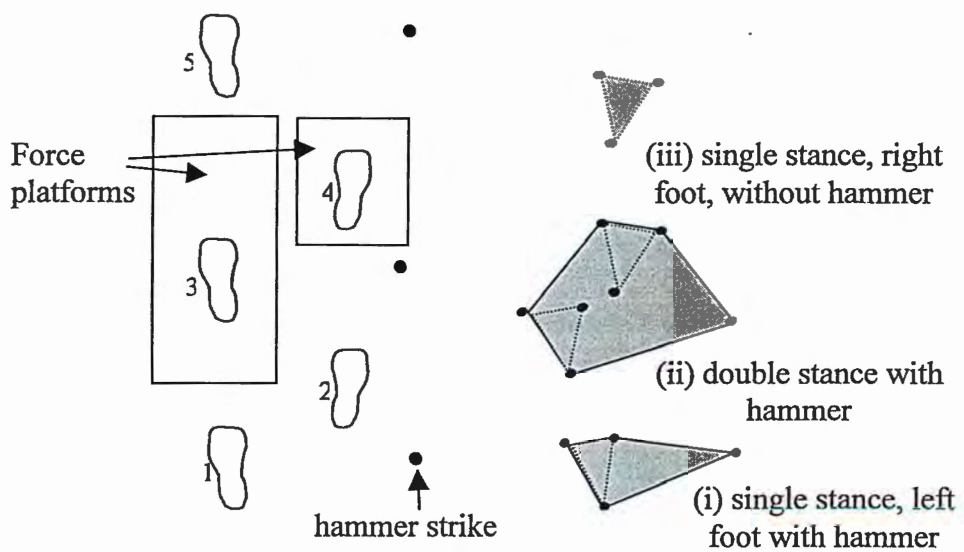
The marker system for gait was the 21-marker system (see section C.4.b.2.). Walking was performed using a hammer in their right hand. The hammer was used as a cane and provided more stability. This hammer strikes the ground, approximately, with the left foot. Markers were added at the top and bottom of the hammer so that the location of the hammer could be determined. See Figures 14 and 15 for Gait BOS configurations.

Figure 15. Stick figure for mining gait:



During a gait cycle there were several possible BOS configurations based on the stance:

1) right foot (single stance)
2) right foot and hammer (double stance)
3) right foot, hammer and left foot (triple stance)
4) left foot (single stance)



(a) example of gait cycles with "hammer walk". The hammer was held in the right hand and used as a cane.

(b) examples of potential BOS boundaries during "hammer walk"

Figure 16. Description of BOS boundaries for gait dynamic balance testing.

C.4.c. Subjective Measurements
C.4.c.1. Perceived exertion

Subjects were asked their perceived sense of exertion after each trial level using Borg's Self-Rating Scale which ranges from 6, which is "very, very light", to 20, which is "very, very hard" perceived exertion (see Appendix I).

C.4.c.2. Rating of Perceived Sense of Slip/Fall (PSOS)

The PSOS scale included four questions regarding the subject's experience of postural instability while performing the task on the inclined surface (see Appendix J). 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 PSOS score. Eight meant that they perceived the greatest instability. This summed score was used in the statistical analyses.

C.4.c.3. Slip/Fall Observations

All subjects wore a safety harness and kneepads to minimize the potential for injury during the testing. The facilitator observed the subject for every trial and noted either yes or no (0 or 1) if the subject slipped or fell during the trial. A slip was defined as a visual sign of lateral movement of the foot on the force platform surface. A fall was defines as an unrecoverable slip, where the subject slipped off the plate and there was an obvious "tug" or pull on the lanyard of the safety harness.

C.4.c.4. Body Part Discomfort Rating

A body part discomfort rating was collected before the session began and after the session was finished. The Bishop-Corlett scale (see Appendix K) was used which divides the body into neck, right/left shoulders, right/left upper arms, right left forearms, right/left wrists, right left hands, upper back, lower back, hips/waist, buttocks, right/left thighs, right left knees, right/left lower legs/feet and right/left ankles (32). Discomfort was ranked from "0" indicating comfortable to "3" indicating extremely uncomfortable.

C.4.d. Light Meter Readings

A light meter (Model 840021, Sper Scientific Ltd, Scottsdale, AZ) 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 kneeling on the force platform in the poor and glare light conditions (good light condition was only used for the baseline test). Measurements were taken, while wearing the Miners cap, 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) for static balance testing. Ambient measurements (at arms length in from of the eyes) were taken 2 steps before the plate, 1 step before the plate, on the plate, 1 step after the plate and 2 steps after the plate, all while wearing the Miners cap.

C.5. Experimental Procedures

All subjects, upon completing the health screening (see section C.1.a.), signed an informed consent form, which had been approved by the University of Cincinnati Institutional Review Board [IRB] (Appendix L) and had the experiments explained to them. Each subject completed 3 sessions, each consisting of balance and gait dynamic balance testing, which were randomized and blocked by surface type. For laboratory testing a session consisted of both balance and gait dynamic balance testing, and the subject had the option to complete as many sessions as they felt comfortable performing back-to-back, or they had the option of completing the sessions on 3 consecutive days. In the field, a session consisted of static balance testing only. Subjects completed all 3 balance sessions back-to-back on the same day. At the beginning of each session, the subject completed a session interview (see Appendix M). This questionnaire collects information on the day of testing such as sleep duration, eating, caffeine intake, alcohol intake, sickness, injuries and pregnancy. In addition, using the Bishop-Corlett scale a body part discomfort rating was collected before the session began and after the session finished (see section C.4.c.4). Upon completion of the questionnaire, the subject was dressed in laboratory-supplied shirt, shorts, socks and shoes and donned a safety harness. This safety harness was worn throughout the duration of testing and was attached to a safety lanyard to prevent the subject from falling to the floor in the event of a slip or fall during testing. The reflective markers were then placed as described in section C.4.b.1. Data collection then began for the session. In the laboratory, balance sessions were completed first, followed by gait for the same surface. The next surface (i.e. next session) was then introduced.

D.5.a. Postural Static balance testing

Before data collection began for balance trials, each task (described in section C.2.e) was explained and practiced by the subject. Each subject completed a total of 48 balance trials (1 shoe type, 3 surface conditions, 2 lighting conditions, 2 postures and 4 tasks) lasting 30 seconds each. The tester observed and recorded whether or not the subject slipped and/or fell during each trial. The tester also administered the PSOS and RPE questions following each trial.

D.5.b. Gait dynamic balance testing

Following the static balance testing for a surface the subject was allowed to rest while the setup was changed to facilitate gait dynamic balance testing. Additional feet markers were placed on the subject (see section C.4.b.2). Each task was explained and practiced by the subject (see section C.2.f). Each subject completed a total of 24 gait trials (2 shoes, 3 surface conditions, 2 lighting conditions, 2 tasks). The tester observed and recorded whether or not the subject slipped and/or fell during each trial. The tester also administered the PSOS and RPE questions following each trial.

C.6. Dependent Variables

C.6.a. Determination of Postural Sway and Objective Measures of Postural Instability

Sway area (SA) is the area of the projection of the body's center of pressure (CP) on the horizontal xy plane due to sway, and sway length (SL) is the distance traveled by the CP during the testing period. We have used these variables in several research studies in our laboratory (11-16). The definition of Maximum Sway antero-posterior (AP) excursion and Maximum Sway medio-lateral (ML) excursion are given in the following.

C.6.a.1. 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 force due to body movement. Thus, the excursion parameters provide an indirect measure of the dynamic stability performance during a given posture.

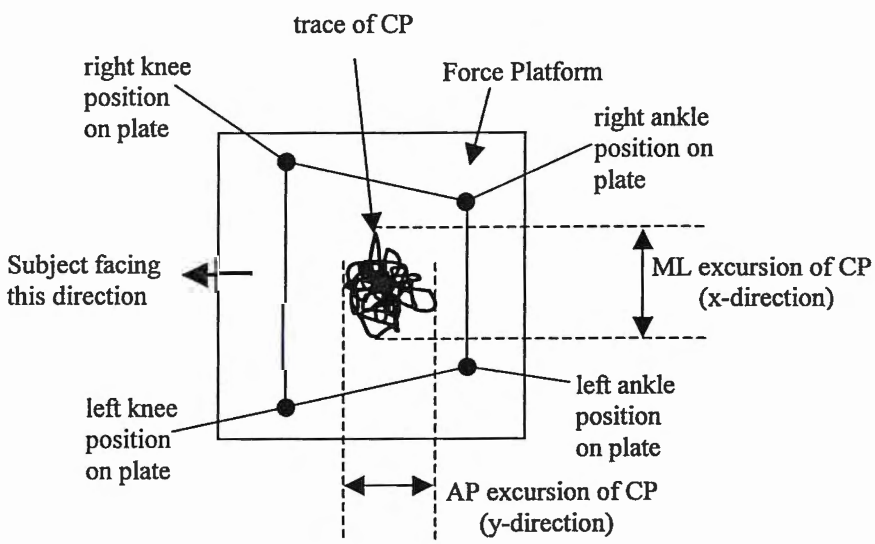


Figure 17. Schematic representation of Excursion of CP in the ML and AP

C.6.a.2. Postural Instability Parameters

Three non-dimensional indices, which are based on those described by Bagchee et al (14), were used to quantitatively determine the propensity of momentary loss of postural balance and/or instability associated with a sway pattern formed by the CG and CP with respect to the postural stability boundary (basal support area). The indices based on CP refer to postural instability, while the indices based on CG refer to postural unbalance. The stability boundary used to determine CG-based postural instability was used for dynamic tasks and are described in our earlier publications (11,14,16,31). 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. A lower value of IPSB implies 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 the stability boundary. The equation is as follows:

$$IPSB = \frac{p}{Rmax} \qquad \text{Eq. (1)}$$

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.

The stability boundaries used for the one-knee and two-knee postures are shown in figures 13 and 14 (in section C.4.b.5).

Negative IPSB Results

The stability boundary is determined by the custom software (IPSB 2000, version. 1.1.10 Copyright All Rights Reserved, University of Cincinnati, 1998-2003) through connecting the markers placed on the BOS. The BOS will change depending on the one knee or two-knee posture. Right ankle, right knee, and left ankle for one knee position or the right ankle, right knee, left knee, and left ankle for the two-knee kneeling posture (Figure 18). Since the true stability boundary can extend beyond the marker placement (tip of toes rather than the ankle) in some trials the IPSB had a negative value, implying that the subject's CP or CG was outside the stability boundary while in fact they were still inside the true stability boundary. Therefore, if the CP or CG falls in the shaded area, it is incorrectly characterized by the software as being outside the stability boundary while in fact it is still inside the true stability boundary. During statistical analysis, those negative values were accounted for to indicate that the subject has a greater propensity of postural instability while performing a given task. This was done by adding a positive number to all IPSB values before performing the analysis (in this case 3.0 for CG based analysis and 2.0 for CP based analysis). The same number was subtracted again before reporting the geometric means. Figure 18 shows the difference between the true and virtual stability boundaries.

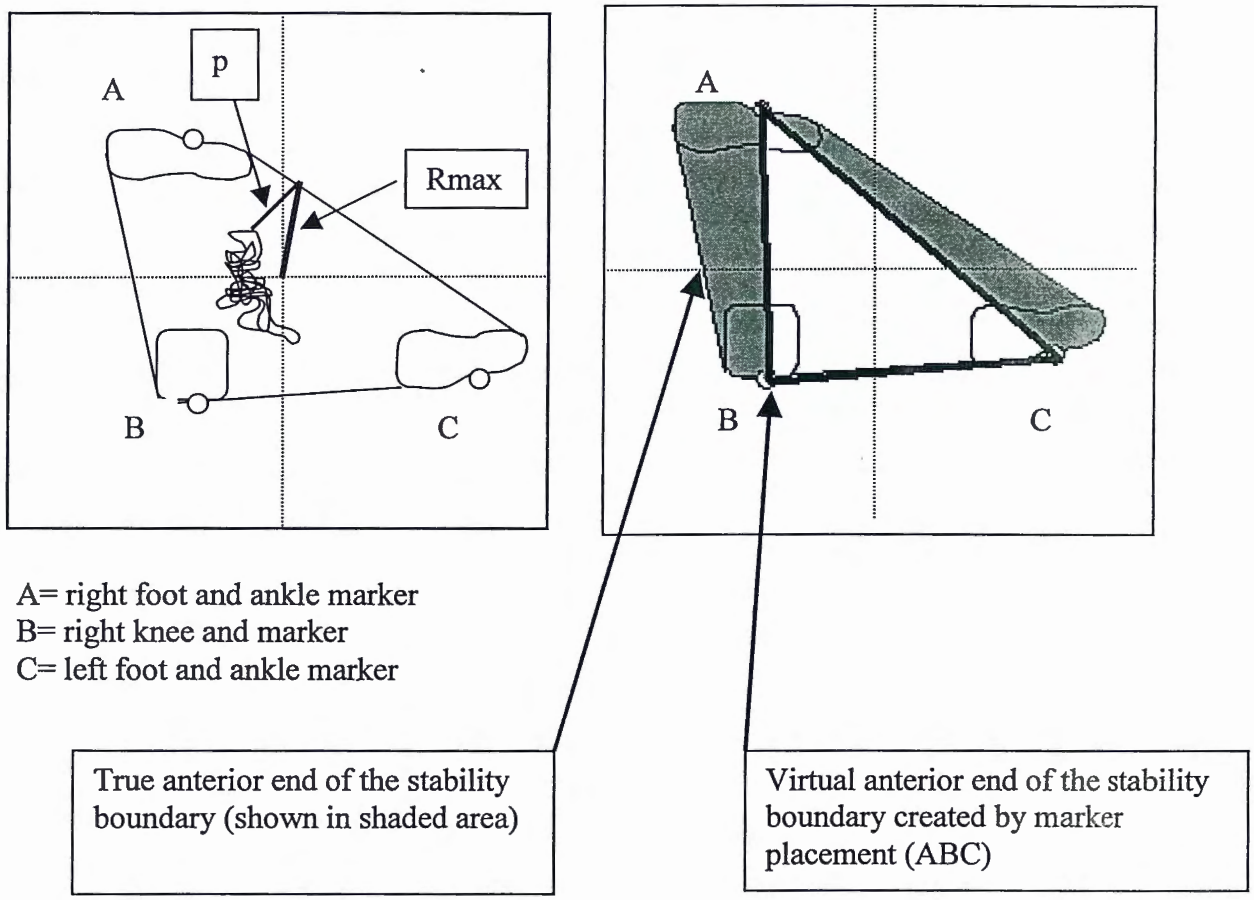


Figure 18. True and Virtual Stability Boundaries during One knee kneel Static Balance Trial

<u>Weighted Residence Time Index (WRTI)</u>

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. A higher WRTI implies poorer postural stability. The equation for determining WRTI is shown in the following:

$$\text{WRTI} = K \Sigma e^{i} z_i \qquad \text{Eq. (2)}$$

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):

$$\text{Stability area ratio (SAR)} = A_t / A_{sb} \qquad \text{Eq. (3)}$$

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 or CG approaching the stability boundary and relatively higher postural instability.

C.6.b. Ground Reaction Forces

Ground reaction forces (GRFs) were calculated for gait trials. GRFs include the following: maximum forces (in Newtons) in the medial, lateral, braking and propulsion directions; contact time (in seconds); the medial/lateral, braking/propulsion and vertical powers (in Joules/second); vertical impact force (in Newtons); the vertical decay rate (in Newtons/second); and the maximum positive and negative torques (in Newton-meters).

C.6.c. Required Coefficient of Friction

From the kinetic data, the horizontal force divided by the vertical force (H/V) is the required coefficient of friction ($COF_{required}$). The minimum, maximum and average $COF_{required}$ were also calculated.

D. RESULTS AND DISCUSSION

D.1. Worker Subjects Demographics

Twenty-five subjects were recruited and tested for this study. Demographic information is shown in Table 12. Worker exercise and mean blood pressure data are shown in Table 13.

Table 12. Worker-Subjects demographic information.

Average Age *yrs* (SD)	Gender	Race	Average Height *cm* (SD)	Average Weight *kg* (SD)	Average Time as a Miner *months* (SD)	Type of Mine(s) Worked In
42.72 (6.87)	3 Female 22 Male	23 Caucasian 2 African American	177.78 (7.66)	95.44 (17.54)	166.2 (99.8)	15 low seam 16 high seam 3 strip mine

Table 13. Worker-Subjects blood pressure and exercise information.

Regular Exercise	Exercise amount	Blood Pressure
9 participate 16 do not	Of the 9 who exercise: average time of *6 hours/week*	*Average BP=129/83* (on the day of testing)

D.2. Muscle Strength Testing

The average results of the postural strength testing performed on the worker-subjects are shown in Table 14.

Table 14. Results for Leg Muscle Strength.

Muscle Group		Mean (lbs.)	SD
Quadriceps	Right	60.3	17.8
	Left	60.0	17.5
Hamstrings	Right	48.0	13.3
	Left	48.9	12.9
Dorsiflexors	Right	49.7	14.2
	Left	50.6	13.6
Plantarflexors	Right	70.1	17.8
	Left	70.1	20.3

D.3. Vision Screening

Vision testing was performed on all worker-subjects. A Snellen chart was used to obtain Snellen Equivalents for their dominant eye. Subjects were allowed to wear their glasses, if applicable, therefore the reported results are corrected vision. A Snellen Equivalent of 20/20 is considered good vision. Thirteen worker-subjects scored Snellen Equivalents of 20/20 and the remaining 12 worker-subjects scored Snellen Equivalents of 20/30.

D.4. Light Meter Reading

The average results of the light meter readings are shown in Table 15.

Table15. Results of Average Light Meter readings (footcandles).

	"Poor" lighting					"Glare" lighting				
Balance	Forehead	Right	Left	Ambient		Forehead	Right	Left	Ambient	
	0.49	0.61	0.36	1.09		3.43	0.60	0.45	0.54	
Gait	1	2	3	4	5	1	2	3	4	5
	1.15	1.13	1.32	1.34	1.14	0.32	0.32	0.27	0.49	0.58

D.5. Reaction Time

The average results for the reaction time readings are shown in Table 16. Right hand dominance was recorded for 22 of the worker-subjects and left hand dominance was recorded for the remaining 3 worker-subjects.

Table 16. Results of Average Reaction Time (milliseconds).

Average Arm Reaction Time (SD)	Average Foot Reaction Time (SD)
30.8 (3.9)	35.7 (4.5)

D.6. Examples of raw kinetic and kinematic data during balance and gait trials

Figures 1 - 10 in Appendix N show examples (from one subject) of the corresponding changes in forces (Fx, Fy, and Fz) for balance (1 - 8) and gait (9 - 10) trials using the force platform [one plate (small plate) for the balance trials and two plates (one small and one large plates) for the gait trials] throughout the trial period. Figures 11 – 20 show the corresponding changes in moments (Mx, My and Mz) for balance (11 – 18) and gait (19 – 20). In addition, figures 21 - 30 in Appendix N show whole body CG movements (x, y and z) during balance (21 – 28) and gait (29 – 30) tasks. The numbered vertical lines mark the events for each trial. Events for each task are described below.

D.6.a. Static balance tasks

All static balance tasks were performed for 30 seconds. Tasks were repeated under different environmental conditions following the original study protocol (see section C.2). **Best conditions** imply that the subject performed the task on firm dry surface, kneeling on 2 knees, and with poor lighting condition. **Worst conditions** imply performing the same task on firm slippery surface, kneeling on 1 knee, and with glare lighting condition.

Stationary
For the stationary task, the subject kneels below the restricted ceiling, relaxed with their wrists resting on each respective thigh for 30 seconds. (**No events** were marked for this task)

Lifting a bucket of bits
For this task, a bucket was lifted from the ground, on the left side of the subject up to a 34" shelf on the right of the subject and returned back to the ground. A voice command to begin the lift was given 8 seconds into the 30 second trial. The subject began the trial kneeling in a relaxed position as in a stationary trial. On the voice command, the subject reached for the bucket and began the lift cycle. **Four events** were marked during this task; 1-beginning of motion, 2-contact with bucket, 3-release of bucket, and 4-end of motion.

Cable lifting
For this task, the subject lifted a section of "cable" from the floor level in front of the force platform, up to the false ceiling and finally replaced the cable to the starting position. The subject began the lift on a voice command given after 8 seconds of inception of the test and relaxed for the remainder of the 30-second test after the lift. **Four events** were marked during this task; 1-beginning of motion, 2-contact with cable, 3-release of cable, and 4-end of motion.

Scaling
For this task, the subject began with a slabber bar in his/her hands and on a voice command raised the bar and insert it into position A marked on the scaling structure. The subject "pried" there once and moved the bar to position B and "pried" once there. After the second "pry", the subject returned the bar to the starting position for the remainder of the 30-second test. **Two events** were marked during this task; 1-beginning of motion and 2-end of motion.

D.6.b. Dynamic balance tasks

For gait trials, the subjects were asked to squat below a certain height marked by ropes (44 inches simulating working in a low seam mine) before beginning to walk and to remain low throughout the trial. Subjects were asked to walk in one direction, and step on two force plates to achieve one heel strike per plate during the gait cycles. The gait for the miners was done with a hammer in their right hand. They used it as a cane and it added another "foot" to their base of support. This hammer struck the ground approximately with the left foot, and the gait setup was made in such a way that the hammer did not strike any of the force plates during the trial. (see Section C.4.a. for more details).

Best conditions imply that the subject performed the task on firm dry surface, with poor lighting condition, wearing leather boots, and carrying no weight. **Worst conditions** imply performing the same task on firm slippery surface, with glare lighting condition, wearing rubber boots, and carrying a 14.5 kg (20 lbs) bag of rice of their back, supported by their left arm (the bag of rice was used to simulate a manual material handling task common in mines).

Nine events were marked during gait trials; 1-left heel strike on the large plate, 2-hammer strike, 3-right toe off, 4-hammer off, 5-right heel strike on small plate, 6-left toe off, 7-left heel strike on ground, 8-hammer second strike, and 9-right toe off.

D.7. Statistical Methods

The data files were imported into the Statistical Analysis System (SAS) for data analysis. Continuous outcomes were analyzed in a mixed repeated measure analysis of covariance models by SAS Proc Mixed; discrete outcomes were analyzed by SAS Proc Genmod. Sway length, sway area and the IPSB outcomes were transformed to their natural logarithm to achieve approximate normality. A list of the outcome variables that were analyzed is given in Appendix O. In the models for the static balance outcomes, the main effects of surface type (firm-dry, uneven-dry or firm-slippery), footwear worn (shoe or boot), task (stationary, cable, bits or scaling), posture (1 knee or 2 knees), and lighting condition (poor or glare) were included as classification variables. In the models for the dynamic balance (gait) outcomes, surface type (firm-dry, uneven-dry or firm-slippery), footwear worn (shoe or boot), lighting condition (poor or glare) and whether a weight was carried (yes or no) were included as classification variables. Two-factor interactions among each of these main effects were also included in the initial models, as were covariates (see Appendix O for a list of covariates included in the statistical models). Backward elimination of insignificant interactions and covariates was performed until final models were determined that included only the main effects and significant two-factor interactions and covariates. Least square means are reported for continuous outcomes and odds ratios for discrete outcomes. An alpha-level of 0.05 was used to judge significance in all models.

D.8 Analyses of Static balance outcomes

D.8.a. Postural Sway and Required Coefficient of friction (H/V) Outcomes

See Tables 17-23 for Postural Sway and Required Coefficient of friction (H/V) results. An increase in postural sway variables implies potential postural instability and an increase in H/V implies that the task carried out requires an increased level of shoe-floor friction. In the following the table of significant findings for main effect, cofactors and interactions is shown. The remaining tables and figures of least squares means of the significant findings are given in Appendix P.

The results from the laboratory based data (n=18) only provided the following responses. Task performed significantly affected each of the sway outcomes ($p<0.0001$, all tests). The stationary task evoked less sway area, sway length, excursion in the medio-lateral (ML or X) and anterior-posterior (AP or Y) directions and maximum required coefficient of friction (H/V). For most of these outcomes, the bits task elicited the greatest postural sway response, 13907% greater than the stationary task in the case of sway area, 351% greater for sway length, 2301% greater for excursion in the ML direction, 1514% for excursion in the AP direction and 1066% for maximum H/V. These responses imply that during bits tasks which requires side-to-side motion the miners' postural stability is at a increased risk and requires an increased shoe-floor friction levels compared to the other three tasks which requires primarily no movement (stationary task) or movements primarily in the sagittal plane only (scaling task and cabling task). The mean sway responses for the cable and scaling tasks were typically between those of the stationary and bits tasks, with the exception of sway length and maximum H/V, in which these tasks elicited slightly greater sway than did the bits task, and excursion in the ML direction, in which the cable task elicited the greatest sway (2254% greater excursion than the stationary task). The results from combined data from the laboratory (n=18) and field (n=7) were comparable to those of laboratory data (described above) only for SA and SL variables for task effect ($p=0.0001$). For the combined data set max H/V and excursions in the ML and AP directions did not show any significant effects for task. While max H/V was not found to be significantly associated with tasks the observed slips showed relatively higher slip incidence for bits (19.4%), cable (18.9%) and scaling (16.3%) tasks compared to the stationary tasks (4%). Irrespective of lab data set or the combined data set the general trend in comparison to stationary task indicated that all other tasks produced significantly higher postural sway implying increased threat to the postural stability. The differences in sway responses among bit tasks, scaling tasks and the cable tasks were not significant.

For the laboratory data only (n=18), posture significantly affected three of the postural sway outcomes (sway area, p<0.05; excursion in the ML direction, p<0.0001; excursion in the AP direction, p<0.02) and maximum H/V (p<0.003). A one-knee posture was associated with somewhat greater sway area (9.2%) but lessened excursion (13.4% and 6.2% for the ML and AP directions, respectively) and maximum H/V (9.1%), as compared to a two-knee posture. The results from combined data from the laboratory (n=18) and field (n=7) were comparable to those of laboratory data (described above) only for SL variables posture effect (p=0.014). For the combined data set the posture and surface were significantly (p=0.03) interacted for SL. For the firm-dry and the firm slippery condition, the SL response was 1.3% and 6.3% respectively, higher for the one knee compared to 2 knee posture implying that use of one knee posture may be prone to postural instability requiring more postural muscle efforts. This is consistent with the finding of higher incidence of slipping with one knee (16.2%) than with two-knee (13.2%) posture during mining task performance.

For the laboratory data only (n=18) the type of surface significantly affected one of the postural sway outcomes (excursion in the AP direction, p<0.02) and the maximum H/V (p<0.02). Excursion in the AP direction was found to be least for the firm-slippery surface (7.5% less than the firm-dry and 8.8% less than the uneven-dry surface). The uneven-dry surface had the greatest maximum H/V (2.2% and 11.0% greater than the firm-dry and firm-slippery surfaces, respectively). The maximum H/V observed for uneven-dry surface implies the requirement of highest shoe-floor COF. In this study leather steel-toe shoe provided a COF of 0.59 for the uneven-dry surface, which appears to be sufficient to produce only 3.8 % observed slips compared to 36.3% slips for the firm-slippery surface.

Lighting was not found to be significantly (it was borderline significant at p=0.055) associated with any of the postural sway outcomes when only the laboratory data (n=18) was used. When both laboratory (n=18) and field data (n=7) were included, lighting significantly affected sway length (p<0.02), with glare evoking slightly greater (3.7%) sway than did poor lighting.

For the laboratory data only (n=18) task was significantly interacted with posture for all of the sway outcomes and maximum H/V. The greatest sway area (p<0.0001), sway length (p<0.005) and excursion in the ML direction (p<0.0001) were found for the bits task when miners employed the two-knee posture. The largest excursion in the AP-direction (p<0.003) and maximum H/V (p<0.02) were experienced by miners during the cable task while in the two-knee posture. When field data (n=7) was added to the laboratory data (n=18), task was also interacted with posture for SA (p=0.0001) and SL (p=0.0001).

For the laboratory data only (n=18), task was also significantly interacted with surface type for three of the postural sway outcomes (all but excursion in the ML direction) and the max H/V variable. For the bits, cable and scaling tasks the SA and SL responses were the lowest for the firm-slippery surface compared to firm-dry and uneven-dry surfaces implying a cautionary body movement on slippery surface. The greatest sway area ($p<0.05$) was experienced for the bits task while the miners were on a firm-dry surface. The greatest sway length ($p<0.04$) was found for the cable task while the miners were on an uneven-dry surface. The greatest excursion in the AP direction ($p<0.02$) was found for the cable task executed on a firm-dry surface. The highest maximum H/V ($p<0.03$) was found for the cable task performed on an uneven-dry surface. When field data (n=7) was added to the laboratory data (n=18), task was also interacted with surface for SA (p=0.0040) and SL (p=0.0082). The increased sway responses on firm dry and uneven dry surfaces suggests that miners' were more confidently letting the body move according to the necessary task associated demand probably because a dry surface provided them with safe footing.

For the laboratory-based data (n=18), only the excursion in the ML direction model included significant covariates. Average foot reaction time, mean blood pressure and the type of mine in which the subjects worked were found to affect this outcome. When including the field data (n=7) to the laboratory data (n=18), regular exercise was found to be a significant predictor of sway area and type of mine was found to be significantly associated with sway length.

Table 17. Main Effects, Significant Covariates and Interactions for SA (Lab and Field).

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	69	5351.24	**0.0001**
Posture	1	23	7.03	**0.0143**
Surface	2	44	0.75	0.4766
Lighting	1	23	3.96	0.0587
Regular Exercise	1	22	11.93	**0.0023**
Task*Posture	3	60	57.21	**0.0001**
Task*Surface	6	132	3.37	**0.0040**

Table 18. Main Effects, Significant Covariates and Interactions for SL (Lab and Field).

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	69	3110.32	**0.0001**
Posture	1	23	1.37	0.2539
Surface	2	44	0.54	0.5842
Lighting	1	23	7.49	**0.0117**
Mine Type	4	19	3.65	**0.0228**
Task*Posture	3	60	15.94	**0.0001**
Task*Surface	6	132	3.04	**0.0082**
Posture*Surface	2	44	3.73	**0.0318**

Table 19. Main Effects and Significant Interactions for SA (Lab only).

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	49	3721.40	**0.0001**
Posture	1	18	4.70	**0.0437**
Surface	2	32	0.71	0.4982
Lighting	1	18	1.66	0.2139
Task*Posture	3	40	29.14	**0.0001**
Task*Surface	6	89	2.31	**0.0405**

Table 20. Main Effects and Significant Interactions for SL (Lab only).

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	49	2285.21	**0.0001**
Posture	1	18	1.14	0.2995
Surface	2	32	0.61	0.5478
Lighting	1	18	4.19	**0.0555**
Task*Posture	3	40	5.01	**0.0048**
Task*Surface	6	89	2.38	**0.0355**

Table 21. Main Effects, Significant Covariates and Interactions for ML-Excursion X (Lab only).

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	46	1024.64	**0.0001**
Posture	1	17	31.87	**0.0001**
Surface	2	26	2.40	0.1106
Lighting	1	17	2.11	0.1648
Avg. Foot Reaction Time	1	12	9.45	**0.0097**
Mean Blood Pressure	1	617	5.89	**0.0156**
Mine Type	4	12	3.74	**0.0336**
Task*Posture	3	38	58.50	**0.0001**

Table 22. Main Effects and Significant Interactions for AP-Excursion Y (Lab only).

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	49	701.00	**0.0001**
Posture	1	18	6.49	**0.0202**
Surface	2	32	5.07	**0.0123**
Lighting	1	18	0.19	0.6684
Task*Posture	3	40	5.48	**0.0030**
Task*Surface	6	89	2.94	**0.0116**

Table 23. Main Effects and Significant Interactions for Maximum H/V (Lab only).

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	49	474.15	**0.0001**
Posture	1	18	11.39	**0.0034**
Surface	2	32	4.94	**0.0135**
Lighting	1	18	0.05	0.8260
Task*Posture	3	40	4.15	**0.0118**
Task*Surface	6	89	2.55	**0.0250**

D.8.b. Postural stability outcomes (CP-based)

See Tables 24-26 for CP-based postural stability results. In the following the table of significant findings for main effect, cofactors and interactions is shown. The remaining tables and figures of least squares means of the significant findings are given in Appendix Q. An increase in SAR and WRTI and lower value of IPSB implies poorer postural balance.

Based on laboratory data set (n=18), task was a significant predictor of all 3 postural stability outcomes (minimum IPSB, p<0.0001; SAR p<0.0001; and WRTI, p<0.04). This is comparable to what was found with postural sway response data set in the previous section. The stationary task elicited the largest IPSB, followed by scaling and the bits task, while the cable task evoked the least IPSB. SAR was greatest during the bits task, followed by the cable, scaling and stationary tasks. WRTI was highest during the cable task, followed by the scaling and bits tasks, with the stationary task having the least WRTI. Based on these three postural stability indices the stationary task is the least unstable and the most unstable task is the cabling followed by bit tasks and then the scaling task.

Posture was also significantly associated with all 3 postural stability outcomes (minimum IPSB and WRTI, p<0.0001; SAR, p<0.0008). The one knee task elicited lesser IPSB and greater SAR and WRTI than did the two knee task which is consistent with the sway responses reported in the previous section, which further supports the finding of higher incidence of slips for the one knee posture than those with two knee postures.

Surface type and lighting were not significant in any of the models for the postural stability outcomes.

A significant task by posture interaction (p<0.0003) suggested that SAR was greatest for the one knee posture performed for the bits task.

BMI was found to be significantly related to minimum IPSB and mean blood pressure was found to be associated with WRTI.

Table 24. Main Effects and Significant Covariates for CP-based IPSB minimum.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	42	32.96	**0.0001**
Posture	1	16	495.73	**0.0001**
Surface	2	30	1.08	0.3508
Lighting	1	16	0.25	0.6270
Body Mass Index	1	15	6.28	**0.02**

Table 25. Main Effects and Significant Interactions for CP-based SAR.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	42	209.70	**0.0001**
Posture	1	16	17.17	**0.0008**
Surface	2	30	1.38	0.2682
Lighting	1	16	1.09	0.3113
Task*Posture	3	33	8.15	**0.0003**

Table 26. Main Effects and Significant Covariates for CP-based WRTI.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	39	3.00	**0.04**
Posture	1	15	571.74	**0.0001**
Surface	2	24	0.32	0.7316
Lighting	1	15	0.27	0.6141
Mean Blood Pressure	1	471	6.17	**0.01**

D.8.c. Postural stability outcomes (CG-based)

See Tables 27-29 for CG-based postural stability results. In the following, the table of significant findings for main effect, cofactors and interactions is shown. The remaining tables and figures of least squares means of the significant findings are given in Appendix R. An increase in SAR and WRTI and lower value of IPSB implies poorer postural balance.

Based on laboratory data (n=18) only, task was a significant predictor of all 3 postural static balance outcomes ($p<0.0001$). The stationary task produced the greatest minimum IPSB, followed by the scaling and the bits task, while the cable task caused the least minimum IPSB. SAR and WRTI were greatest during the bits task, followed by the cable, scaling and stationary tasks.

Posture was also significantly related to all 3 postural stability outcomes (minimum IPSB and SAR, $p<0.0001$; WRTI, $p<0.04$). The one knee task elicited lesser IPSB and greater SAR and WRTI than did the two-knee task. Similar to CP based postural balance variables and the sway variables reported earlier the CG based results provides further support that one knee posture is more prone to producing postural imbalance than those with two knee posture.

Surface type was found to be associated with minimum IPSB ($p<0.05$) and WRTI ($p<0.007$). The firm-dry and uneven-dry surfaces produced less IPSB than did the firm-slippery surface. The firm-dry surface produced less WRTI than the uneven-dry and firm-slippery surfaces. Based on the above response the firm-slippery surface was more threatening to postural balance.

Lighting was not significant in any of the models for the CG-based IPSB outcomes. The task by posture interaction was found to be significant for all 3 postural static balance outcomes ($p<0.0001$). Minimum IPSB was highest for the two knee posture while performing the scaling and stationary tasks and lowest for the one knee posture while performing the bits and cable tasks. SAR was greatest for the one knee posture during the bits task. WRTI was highest for the 2-knee posture during the cable task.

Significant covariates in these models included mean blood pressure, regular exercise, physical effort level, and number of hours participating in an exercise program and average arm and foot reaction time.

Table 27. Main Effects, Significant Covariates and Interactions for CP-based IPSB minimum.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	45	208.04	**0.0001**
Posture	1	15	705.61	**0.0001**
Surface	2	23	3.50	**0.047**
Lighting	1	15	3.08	0.0997
Mean Blood Pressure	1	550	5.64	**0.018**
Regular Exercise	1	14	8.10	**0.013**
Task*Posture	3	44	9.15	**0.0001**

Table 28. Main Effects, Significant Covariates and Interactions for CP-based SAR.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	45	669.23	**0.0001**
Posture	1	15	83.84	**0.0001**
Surface	2	25	0.08	0.9208
Lighting	1	15	2.61	0.1271
Avg. Foot Reaction Time	1	13	9.71	**0.0082**
Physical Effort Level	1	576	10.97	**0.0010**
No. of hours per week exercise	1	13	18.78	**0.0008**
Task*Posture	3	43	13.34	**0.0001**

Table 29. Main Effects, Significant Covariates and Interactions for CP-based WRTI.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	48	21.19	**0.0001**
Posture	1	16	5.39	**0.034**
Surface	2	29	5.90	**0.0071**
Lighting	1	16	0.19	0.67
Avg. Arm Reaction Time	1	15	4.92	**0.042**
Task*Posture	3	46	19.12	**0.0001**

D.8.d. Perceived Exertion and Perceived Sense of Slip (PSOS) Outcomes for Static balance tasks

See Tables 30-31 for PSOS and RPE results. In the following the table of significant findings for main effect, cofactors and interactions is shown. The remaining tables and figures of least squares means of the significant findings are given in Appendix S.

Based on combined laboratory (n=18) and field (7) data, task significantly affected both perceived exertion (RPE) and perceived sense of slip (PSOS) ($p<0.0001$). RPE and PSOS were both rated to be least during the stationary task. This is consistent with the objective measure of postural sway and stability responses reported in the above. RPE was rated to be the greatest during the scaling task (28.4% higher than the stationary task) and only slightly less for the cable and bits task (22.1% and 21.5%, respectively, higher than the stationary task). PSOS was rated to be greatest during the scaling task (166% greater than the stationary task), followed by the bits (145% greater) and the cable (137% greater than the stationary task) tasks.

Type of posture was found to be significantly related to both RPE ($p<0.02$) and PSOS ($p<0.0001$). A one-knee posture was rated higher in terms of both RPE (2.8%) and PSOS (33.5%) as compared to a two-knee posture, which is consistent with objective measures of postural sway and stability/balance. In other words PSOS was accurately rating the one knee posture to be more threatening to postural stability/balance than that with two knee posture.

Type of surface was associated with both RPE ($p<0.009$) and PSOS ($p<0.0001$). A firm-slippery surface was rated as eliciting the most exertion (5.0% greater than a firm-dry surface), followed by an uneven-dry surface (4.6% greater), with the least exertion perceived for the firm-dry surface. PSOS was greatest for the firm-slippery surface, 59.6% greater than the uneven-dry surface and 53.3% greater than the firm-dry surface. The PSOS response implies that the body accurately perceived the threat to the postural balance due to changes in surfaces, which should have as a corrective postural muscle action actually reduced the postural sway responses in an effort to minimize postural instability. However, only excursion in AP direction was significantly reduced for the firm-slippery surface condition. Based on postural stability indices of minimum IPSB and WRTI the firm-slippery surface produced poorer postural stability in spite of body's ability to correctly perceive the threat of the surface associated postural instability. This miss-match between perception and the objective measure of the postural instability provides evidence that under certain risk factors human body is not capable of deploying the necessary postural corrective muscle actions.

The miners found glare to increase PSOS ($p<0.05$); 11.9% greater PSOS was reported during the glare condition as compared to poor lighting.

A task by surface interaction suggested that the greatest RPE was experienced by the miners while performing the scaling task on an uneven-dry surface ($p<0.05$).

A number of covariates influenced the miners' RPE, including physical effort level, and two muscle strength variables (RQ and RD). Physical effort level, mean blood pressure, RQ and the number of hours per week spent exercising were significant covariates of the PSOS outcome.

Table 30. Main Effects and Significant Covariates for Balance PSOS.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	63	45.46	**0.0001**
Posture	1	21	29.27	**0.0001**
Surface	2	19	20.64	**0.0001**
Lighting	1	21	4.50	**0.046**
Physical Effort Level	1	652	8.99	**0.0028**
Mean Blood Pressure	1	652	4.96	**0.026**
Average Right Quadriceps	1	19	9.03	**0.0073**
No. of hours per week exercise	1	19	7.57	**0.013**

Table 31. Main Effects, Significant Covariates and Interactions for Balance RPE.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Task	3	69	85.99	**0.0001**
Posture	1	23	6.2	**0.02**
Surface	2	25	5.7	**0.0091**
Lighting	1	23	3.83	0.0625
Physical Effort Level	1	773	3.94	**0.047**
Average Right Quadriceps	1	21	5.26	**0.032**
Average Right Dorsiflexors	1	21	4.43	**0.047**
Task*Surface	6	75	2.25	**0.047**

D.8.e. Slips and Falls during static balance tasks

See Table 32 for Observed Slip results. In the following the table the significant findings for main effects are shown. The remaining tables of odds ratios are given in Appendix T.

Table 32. GENMOD procedure for Observed Slip during static balance tasks.

Source	DF	Chi-Square	Pr>ChiSq
Task	3	13.32	**0.004**
Posture	1	3.82	**0.051**
Surface	2	14.95	**0.0006**
Lighting	1	5.63	**0.018**

Based on combined data from lab (n=18) and field (n=7) the type of surface was found to be significantly related to slips (p<0.0006). A slip was much more likely on the firm-slippery surface than on either the firm-dry surface (OR=16.7) or the uneven-dry surface (OR=16.7). The percentage of trials producing slips ranked highest for firm-slippery surface (36.3%) and the firm-dry and uneven-dry surfaces came in second with 3.8% slips each. The type of task (p=0.004) performed and the environmental lighting (p=0.018) were significantly related to slips. Overall all tasks combined produced 14.6% of slips among all the trials performed in this study. A slip was 7.5 and 1.24 times more likely to occur when performing a bit task as compared to the stationary and the scaling task respectively. The likelihood of slip occurrence during cable and bit tasks was the same. In comparison to stationary task the slip was much more likely than on either cable task (OR=7.5) or the scaling task (OR=1.42). The likelihood of slip occurrence during poor environmental lighting was 1.6 times higher than that for glare lighting. The type of posture used during task performance was marginally (p=0.051) significantly related to slips. The use of one knee posture was 1.42 times more likely to cause slips when compared to the two-knee posture. This is consistent with postural instability response data (both CP and CG based) where one knee posture produced smallest value of IPSB, and largest amount of SAR and WRTI compared to that for two-knee posture implying that former posture is more unstable. Based on postural instability indices the performance of bits task and cable task with one knee caused a relatively higher postural instability compared to stationary and scaling tasks. The percentage of trials producing slips ranked highest for the bit task (19.4%) followed by cable (18.9%), scaling (16.3%) and stationary tasks (4%). See Appendix U for frequency of slips/falls.

D.9. Analyses of Dynamic balance (gait) outcomes
D.9.a. Ground Reaction Forces of Right Foot (GRR) outcomes

See Tables 33-44 for GRR results. In the following the table of significant findings for main effect, cofactors and interactions is shown. The remaining tables and figures of least squares means of the significant findings are given in Appendix V.

All gait evaluations were carried out in the laboratory with the entire cohort (n=25). Type of surface was significantly associated with 10 of the 12 GRR outcomes. The uneven-dry surface required the greatest maximum medial force (p<0.0001), maximum braking force (p<0.0001), maximum propulsion force (p<0.0001), maximum lateral force (p<0.0001), medial/lateral power (p<0.0001), braking/propulsion power (p<0.0001), vertical power (p<0.002), maximum positive torque (p<0.0001) and maximum negative torque (p<0.0001). For each of these nine outcomes, the firm-dry surface followed the uneven-dry surface in terms of force, power or torque required, with the firm-slippery eliciting the least force, power or torque. This was expected, as the firm-slippery surface does not provide the necessary foot-floor surface friction to allow development of adequate ground reaction forces and moments necessary for safe upright balance. Because of this, subjects' ability to maintain safe upright balance without slips/falls may be jeopardized while carrying out tasks on slippery surface. This is supported by the fact that firm-slippery surface produced the highest level of slip incidence (83% of trials produced slips) and fall incidence (8% of trials produced falls) Appendix U. The differences between the uneven-dry and the firm-slippery surfaces ranged between 8.8% (vertical power) and 193% (maximum positive torque). The differences between the firm-dry and the firm-slippery surfaces ranged between 4.7% (vertical power) and 140% (maximum negative torque). Contact time also was affected by surface type ($p<0.0004$), with the firm-slippery surface eliciting the greatest contact time, 1.3% more than the uneven-dry surface and 7.7% more than the firm-dry surface. This increased contact time of the foot on the force plate while walking on firm-slippery surface is indicative of body's cautionary gait pattern assumed for maintaining safe upright balance. This cautionary response to postural balance threat produced by the firm-slippery surface is also supported by the fact that perceived sense of slip (PSOS) score was the highest for this surface condition compared to those for firm-dry and uneven-dry surfaces.

Carrying a weight was significantly related to 5 of the 12 GRR outcomes. Carrying a weight increased the maximum braking force ($p<0.02$), contact time ($p<0.0001$), braking/propulsion power ($p<0.0006$), vertical power ($p<0.0001$) and maximum positive torque ($p<0.04$). These differences ranged between 9.2% (maximum positive torque) and 27.7% (vertical power). During carriage of weight it is expected that above mentioned ground reaction force/torques values will increase so that safe upright balance is maintained. This type of response is consistent with body's perception of increased (PSOS score was highest for the carrying weight condition) threat to postural balance during task performance with a weight in hand.

Five of the 12 GRR outcomes differed significantly according to the type of footwear worn. Shoes exhibited greater maximum propulsion force ($p<0.02$), medial/lateral power ($p<0.02$), braking/propulsion power ($p<0.03$) and maximum positive torque ($p<0.03$) but a slower vertical decay rate ($p<0.002$) as compared to boots. The differences between the two types of footwear ranged from 7.0% (maximum propulsion force) to 12.6% (vertical decay rate).

The type of lighting was not a significant factor in predicting any of the GRR outcomes.

The type of surface and the type of footwear worn were significantly interacted in 6 of the 12 GRR models. Maximum medial force ($p<0.001$), maximum propulsion force ($p<0.002$), medial lateral power ($p<0.0003$), braking/propulsion power ($p<0.001$), maximum positive torque ($p<0.03$) and maximum negative torque ($p<0.02$) were minimized when a boot was worn on a firm-slippery surface. This finding suggest that a combination of wearing a boot on a firm-slippery surface does not provide appropriate foot-floor surface friction for body's ability to generate ground reaction forces/torques necessary for maintaining safe upright balance. This is consistent with lowest dynamic COF (0.16) value found with boot on firm-slippery surface, which actually was associated with highest percentage (39.3%) of slip occurrences among all the trials. On the other hand the steel-toe shoe produced a dynamic COF of 0.22 on a firm-slippery surface, which produced the second highest percentage (33.7%) of slip occurrences among all the trials. This is consistent with studies presented in the literature. Previous studies (28,29,30,31) have shown that for COF values 0.15 to 0.19, a slip is possible but the loss of balance is often recoverable while performing normal walking on a level surface with no task performance i.e. carrying weight. Also previous studies reported that for COF values 0.20 and greater, a slip is not likely to occur if no task is being performed during gait on slippery surface. Since in this study these miners were carrying a weight a COF value of 0.16 and 0.22 may be sufficiently low to cause unrecoverable slips. The firm-dry and uneven-dry surfaces produced dynamic COF values between 0.59 and 1.2.

Lighting was significantly interacted with the type of surface for the maximum braking force ($p<0.02$). Poor lighting combined with walking on an uneven-dry surface produced the greatest maximum braking force.

A number of covariates remained significant predictors of one or more of the GRR outcomes, including: BMI, physical effort level, mean blood pressure, the muscle strength variables, RH, RP, and LP, arm reaction time and months having worked as a miner.

Table 33. Main Effects, Significant Covariates and Interactions for GRR Maximum Medial Force.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	0.43	0.5201
Surface	2	39	76.45	**0.0001**
Lighting	1	23	0.01	0.9056
Footwear	1	23	0.02	0.9030
Body Mass Index	1	22	22.41	**0.0001**
Physical Effort Level	1	480	13.18	**0.0003**
Mean Blood Pressure	1	480	6.13	**0.0136**
Surface*Footwear	2	39	7.95	**0.0013**

Table 34. Main Effects, Significant Covariates and Interactions for GRR Maximum Braking Force.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	6.95	**0.015**
Surface	2	44	105.42	**0.0001**
Lighting	1	23	0.05	0.8196
Footwear	1	23	0.00	0.9920
Physical Effort Level	1	521	10.07	**0.0016**
Average Right Hamstring	1	22	6.15	**0.021**
Surface*Lighting	2	44	4.29	**0.020**

Table 35. Main Effects, Significant Covariates and Interactions for GRR Maximum Propulsion Force.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	3.11	0.0910
Surface	2	46	127.65	**0.0001**
Lighting	1	23	0.38	0.5426
Footwear	1	23	7.56	**0.011**
Body Mass Index	1	22	18.95	**0.0003**
Surface*Footwear	2	46	7.14	**0.0020**

Table 36. Main Effects, Significant Covariates and Interactions for GRR Maximum Lateral Force.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	1.64	0.2131
Surface	2	46	40.31	**0.0001**
Lighting	1	23	0.20	0.6605
Footwear	1	23	1.48	0.2361
Average Right Plantarflexors	1	21	9.23	**0.0062**
Average Left Plantarflexors	1	21	11.38	**0.0029**

Table 37. Main Effects, Significant Covariates and Interactions for GRR Medial/Lateral Power.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	0.07	0.7882
Surface	2	39	55.79	**0.0001**
Lighting	1	23	0.79	0.3847
Footwear	1	23	6.43	**0.018**
Physical Effort Level	1	480	9.06	**0.0027**
Mean Blood Pressure	1	480	4.98	**0.026**
Surface*Footwear	2	39	10.30	**0.0003**

Table 38. Main Effects, Significant Covariates and Interactions for GRR Braking/Propulsion Power.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	15.96	**0.0006**
Surface	2	46	194.42	**0.0001**
Lighting	1	23	0.23	0.6378
Footwear	1	23	5.95	**0.023**
Surface*Footwear	2	46	8.08	**0.0010**

Table 39. Main Effects, Significant Covariates and Interactions for GRR Vertical Power.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	186.34	**0.0001**
Surface	2	46	7.40	**0.0016**
Lighting	1	23	0.96	0.3374
Footwear	1	23	0.52	0.4792
Average Arm Reaction Time	1	21	4.55	**0.045**
Months Working as a Miner	1	21	7.38	**0.013**

Table 40. Main Effects, Significant Covariates and Interactions for GRR Maximum Positive Torque.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	4.97	**0.036**
Surface	2	44	190.99	**0.0001**
Lighting	1	23	0.01	0.9141
Footwear	1	23	5.92	**0.023**
Physical Effort Level	1	521	6.27	**0.013**
Surface*Footwear	2	44	4.05	**0.024**

Table 41. Main Effects, Significant Covariates and Interactions for GRR Maximum Negative Torque.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	0.37	0.5515
Surface	2	39	72.57	**0.0001**
Lighting	1	23	0.58	0.4554
Footwear	1	23	1.08	0.3099
Mean Blood Pressure	1	481	6.64	**0.010**
Surface*Footwear	2	39	4.83	**0.013**

Table 42. Main Effects, Significant Covariates and Interactions for GRR Contact Time.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	67.11	**0.0001**
Surface	2	46	9.18	**0.0004**
Lighting	1	23	1.62	0.2162
Footwear	1	23	0.16	0.6886
Average Arm Reaction Time	1	19	7.64	**0.012**
Average Right Plantarflexors	1	19	5.98	**0.024**
Average Left Plantarflexors	1	19	6.16	**0.023**
Months Working as a Miner	1	19	8.36	**0.0094**

Table 43. Main Effects, Significant Covariates and Interactions for GRR Vertical Decay Rate.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	0.21	0.6475
Surface	2	46	2.59	0.0859
Lighting	1	23	0.16	0.6966
Footwear	1	23	12.53	**0.0017**
Average Right Plantarflexors	1	21	5.51	**0.029**
Average Left Plantarflexors	1	21	4.41	**0.048**

Table 44. Main Effects, Significant Covariates and Interactions for GRR Vertical Impact Force.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	0.99	0.3301
Surface	2	46	2.30	0.1115
Lighting	1	23	0.37	0.5470
Footwear	1	23	0.50	0.4852
Average Right Plantarflexors	1	21	7.56	**0.012**
Average Left Plantarflexors	1	21	7.85	**0.011**

D.9.b. Ground Reaction Forces of Left Foot (GRL) outcomes

See Tables 45-56 for GRL results. In the following the table of significant findings for main effect, cofactors and interactions is shown. The remaining tables and figures of least squares means of the significant findings are given in Appendix W.

Type of surface significantly affected 10 of the 12 GRL outcomes. The uneven-dry surface produced the greatest maximum medial force, maximum braking force, maximum propulsion force, maximum lateral force, medial/lateral power, braking/propulsion power, maximum positive torque and maximum negative torque ($p<0.0001$). The firm-dry surface caused the next greatest amounts of force, power or torque, with the firm-slippery surface producing the least. Similar to GRR response, this was expected, as the firm-slippery surface does not provide the necessary foot-floor surface friction to allow development of adequate ground reaction forces and moments necessary for safe upright balance. Because of this, subjects' ability to maintain safe upright balance without slips/falls may be jeopardized while carrying out tasks on slippery surface. This is supported by the fact that firm-slippery surface produced the highest level of slip incidence (83% of trials produced slips) and fall incidence (8% of trials produced falls). The differences between the uneven-dry and firm-slippery surfaces ranged between 37.3% (maximum medial force) and 320% (maximum negative torque), while the differences between the firm-dry and firm-slippery surfaces ranged between 35.6% (maximum medial force) and 155% (braking/propulsion power). Contact time also differed according to surface type ($p<0.0001$), with the firm-slippery surface inducing the longest contact time, followed by the uneven-dry surface and the firm-dry surface.

Contact times were 20.5% longer for the firm-slippery surface and 6.8% longer for the uneven-dry surface, as compared to the firm-dry surface. Similar to the GRR response, this increased contact time of the foot on the force plate while walking on firm-slippery surface is indicative of body's cautionary gait pattern assumed for maintaining safe upright balance. This cautionary response to postural balance threat produced by the firm-slippery surface is also supported by the fact that perceived sense of slip (PSOS) score was the highest for this surface condition compared to those for firm-dry and uneven-dry surfaces.

A significant difference among surfaces in terms of vertical power indicated that the firm-slippery surface produced the greatest power, followed by the uneven-dry and firm-dry surfaces ($p<0.0001$). Walking on a firm-slippery surface was associated with 14.3% and on an uneven-dry with 11.9% greater vertical power, as compared to walking on a firm-dry surface.

Carrying a weight was significantly associated with 7 of the 12 GRL outcomes. Carrying a weight evoked greater maximum braking force ($p<0.003$), maximum propulsion force ($p<0.02$), contact time ($p<0.0001$), braking/propulsion power ($p<0.0001$), vertical power ($p<0.0001$), maximum positive torque ($p<0.009$) and maximum negative torque ($p<0.0005$). The increases in these outcomes due to carrying a weight ranged between 8.1% (maximum propulsion force) and 32.8% (maximum negative torque). Like GRR response, during carriage of weight it is expected that above mentioned ground reaction force/torques values will increase so that safe upright balance is maintained. This type of response is consistent with body's perception of increased (PSOS score was highest for the carrying weight condition) threat to postural balance during task performance with a weight in hand.

Type of footwear worn significantly affected 6 of the 12 GRL outcomes. Shoes were associated with greater maximum medial force ($p<0.05$), maximum propulsion force ($p<0.005$), medial/lateral power ($p<0.003$), shorter contact time ($p<0.005$), and lesser maximum positive torque ($p<0.005$) and maximum negative torque ($p<0.03$). The differences between shoes and boots ranged between 3.7% (maximum medial force) and 19.4% (maximum positive torque).

Lighting was not found to be significant in any of the GRL models.

Type of surface was found to be significantly interacted with type of footwear worn in 4 of the 12 GRL models. Wearing a boot on a firm-slippery surface minimized the maximum medial force ($p<0.0001$), medial/lateral power ($p<0.03$) and maximum negative torque ($p<0.005$) and produced the longest contact time ($p<0.02$). Similar to GRR response, this finding suggest that a combination of wearing a boot on a firm-slippery surface does not provide appropriate foot-floor surface friction for body's ability to generate ground reaction forces/torques necessary for maintaining safe upright balance. This is consistent with lowest dynamic COF (0.16) value found with boot on firm-slippery surface, which actually was associated with highest percentage (39.3%) of slip occurrences among all the trials. On the other hand the steel-toe shoe produced a dynamic COF of 0.22 on a firm-slippery surface, which produced the second highest percentage (33.7%) of slip occurrences among all the trials. This is consistent with studies presented in the literature. Previous studies (28,29,30,31) have shown that for COF values 0.15 to 0.19, a slip is possible but the loss of balance is often recoverable while performing normal walking on a level surface with no task performance i.e. carrying weight. Also previous studies reported that for COF values 0.20 and greater, a slip is not likely to occur if no task is being performed during gait on slippery surface. Since in this study these miners were carrying a weight a COF value of 0.16 and 0.22 may be sufficiently low to cause unrecoverable slips. The firm-dry and uneven-dry surfaces produced dynamic COF values between 0.59 and 1.2.

Lighting was significantly interacted with carrying a weight in the medial/lateral power model ($p<0.04$). Carrying a weight in glare increased the medial/lateral power exerted. The type of surface and carrying a weight were interacted in the model for maximum negative torque ($p<0.03$). Carrying a weight on an uneven-dry surface produced the greatest maximum negative torque.

A number of covariates remained significant predictors of one or more of the GRL outcomes, including: BMI, age, average blood pressure, arm reaction time, foot reaction time, physical effort level, the muscle strength variables (LD, RD, LP, RP, LQ, RQ, LH, RH), involvement in a regular exercise program, number of hours participating in regular exercise, months having worked as a miner and type of mine in which the worker is employed.

Table 45. Main Effects, Significant Covariates and Interactions for GRL Maximum Medial Force.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	22	4.22	0.0519
Surface	2	39	117.11	**0.0001**
Lighting	1	22	0.57	0.4600
Footwear	1	22	4.65	**0.042**
Body Mass Index	1	17	60.78	**0.0001**
Mean Blood Pressure	1	476	13.65	**0.0002**
Average Left Dorsiflexors	1	17	7.85	**0.012**
Average Left Plantarflexors	1	17	7.07	**0.017**
Regular Exercise	1	17	8.14	**0.011**
No. of hrs per week exercise	1	17	8.13	**0.011**
Surface*Footwear	2	39	17.52	**0.0001**

Table 46. Main Effects, Significant Covariates and Interactions for GRL Maximum Braking Force.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	11.65	**0.0024**
Surface	2	46	152.49	**0.0001**
Lighting	1	23	0.04	0.8364
Footwear	1	23	0.34	0.5649
AGE	1	21	4.37	**0.049**
Average Right Dorsiflexors	1	21	9.84	**0.0050**

Table 47. Main Effects, Significant Covariates and Interactions for GRL Maximum Propulsion Force.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	6.25	**0.020**
Surface	2	44	101.14	**0.0001**
Lighting	1	23	2.60	0.1207
Footwear	1	23	9.62	**0.0050**
Average Arm Reaction Time	1	22	4.87	**0.038**
Physical Effort Level	1	525	8.62	**0.0035**

Table 48. Main Effects, Significant Covariates and Interactions for GRL Maximum Lateral Force.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	2.76	0.1102
Surface	2	46	52.54	**0.0001**
Lighting	1	23	0.31	0.5831
Footwear	1	23	0.18	0.6761
Average Foot Reaction Time	1	10	27.10	**0.0004**
Average Left Quadriceps	1	10	37.39	**0.0001**
Average Right Hamstrings	1	10	34.45	**0.0002**
Average Left Hamstrings	1	10	36.14	**0.0001**
Average Right Dorsiflexors	1	10	22.52	**0.0008**
Average Left Dorsiflexors	1	10	33.44	**0.0002**
Average Right Plantarflexors	1	10	26.65	**0.0004**
Average Left Plantarflexors	1	10	70.63	**0.0001**
Months worked as a Miner	1	10	17.61	**0.0018**
Mine Type worked in	4	10	14.58	**0.0004**

Table 49. Main Effects, Significant Covariates and Interactions for GRL Medial/Lateral Power.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	0.42	0.5216
Surface	2	46	79.56	**0.0001**
Lighting	1	23	2.31	0.1424
Footwear	1	23	11.04	**0.0030**
Body Mass Index	1	22	12.34	**0.0020**
Weight*Lighting	1	23	4.77	**0.040**
Surface*Footwear	2	46	3.76	**0.031**

Table 50. Main Effects, Significant Covariates and Interactions for GRL Braking/Propulsion Power.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	31.95	**0.0001**
Surface	2	44	167.47	**0.0001**
Lighting	1	23	1.43	0.2432
Footwear	1	23	2.69	0.1145
Physical Effort Level	1	525	21.13	**0.0001**

Table 51. Main Effects, Significant Covariates and Interactions for GRL Vertical Power.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	188.05	**0.0001**
Surface	2	46	16.73	**0.0001**
Lighting	1	23	0.21	0.6490
Footwear	1	23	2.45	0.1314

Table 52. Main Effects, Significant Covariates and Interactions for GRL Maximum Positive Torque.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	8.33	**0.0083**
Surface	2	46	88.79	**0.0001**
Lighting	1	23	0.39	0.5403
Footwear	1	23	9.61	**0.0051**

Table 53. Main Effects, Significant Covariates and Interactions for GRL Maximum Negative Torque.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	16.16	**0.0005**
Surface	2	46	107.00	**0.0001**
Lighting	1	23	0.28	0.5991
Footwear	1	23	5.94	**0.023**
Age	1	11	53.83	**0.0001**
Body Mass Index	1	11	23.58	**0.0005**
Average Foot Reaction Time	1	11	60.43	**0.0001**
Average Left Quadriceps	1	11	8.63	**0.014**
Average Left Hamstrings	1	11	56.06	**0.0001**
Average Right Dorsiflexors	1	11	38.94	**0.0001**
Average Left Dorsiflexors	1	11	93.27	**0.0001**
Average Left Plantarflexors	1	11	93.96	**0.0001**
Mine Type worked in	4	11	12.74	**0.0004**
Weight*Surface	2	46	3.91	**0.027**
Surface*Footwear	2	46	5.95	**0.0050**

Table 54. Main Effects, Significant Covariates and Interactions for GRL Contact Time.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	76.50	**0.0001**
Surface	2	46	39.35	**0.0001**
Lighting	1	23	0.82	0.3735
Footwear	1	23	10.07	**0.0042**
Surface*Footwear	2	46	4.91	**0.012**

Table 55. Main Effects, Significant Covariates and Interactions for GRL Vertical Decay Rate.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	1.12	0.3004
Surface	2	46	1.70	0.1947
Lighting	1	23	1.09	0.3069
Footwear	1	23	0.11	0.7451

Table 56. Main Effects, Significant Covariates and Interactions for GRL Vertical Impact Force.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	22	1.09	0.3079
Surface	2	44	1.97	0.1514
Lighting	1	22	0.20	0.6561
Footwear	1	22	0.23	0.6336
Body Mass Index	1	13	16.88	**0.0012**
Average Right Quadriceps	1	13	26.84	**0.0002**
Average Left Quadriceps	1	13	29.40	**0.0001**
Average Left Hamstring	1	13	5.89	**0.030**
Mine Type worked in	4	13	6.27	**0.0049**
No. of hrs regular exercise	1	13	15.33	**0.0018**

D.9.c. Perceived Exertion and Perceived Sense of Slip (PSOS) Outcomes for Dynamic balance tasks

See Tables 57-58 for PSOS and RPE results. In the following, the table of significant findings for main effect, cofactors and interactions is shown. The remaining tables and figures of least squares means of the significant findings are given in Appendix X.

The type of surface significantly affected both the perceived exertion (RPE) and perceived sense of slip (PSOS) outcomes ($p<0.0001$). A firm-slippery surface was rated as producing 8.1% more exertion than a firm-dry surface and 5.2% more than an uneven-dry surface. The firm-slippery surface was rated 93.9% and 86.3% higher, in terms of PSOS, as compared to the firm-dry surface and uneven-dry surfaces, respectively.

Carrying a weight also significantly affected both RPE and PSOS ($p<0.0001$). Carrying a weight induced 20.5% greater RPE and 40.6% greater PSOS than not carrying a weight. This increased perceived level of exertion and slips during carrying weight was consistent with body's response to increase in gait associated changes in gait variables i.e. maximum braking force ($p<0.02$), contact time ($p<0.0001$), braking/propulsion power ($p<0.0006$), vertical power ($p<0.0001$) and maximum positive torque ($p<0.04$). Increases in these variables suggests that during carrying of weight the body's gait pattern changed to reflect cautionary motion requiring extra physical effort on the part of the subject as was demonstrated by increased value of RPE.

Type of footwear worn was found to be significantly related to both RPE ($p<0.0002$) and PSOS ($p<0.0001$). Wearing a boot was associated with 5.6% greater RPE and 31.4% greater PSOS.

Lighting was not significantly related to either RPE or PSOS.

The type of surface and footwear worn were significantly interacted in these factors' relationships with RPE and PSOS ($p<0.0001$). Wearing a boot on a firm-slippery surface produced the greatest RPE and PSOS. Under this type of surface and footwear condition it is expected to find an increased perception of slip, which may require body to assume a cautionary gait pattern to minimize slips and falls. However, in the present experiments firm-slippery condition and the use of boots produced highest percentages of slips and falls (83.4% slips and 8% falls on firm-slippery condition and 39% slips and 5% falls with boots). In other words a cautionary gait demanded by the firm-slippery surface and the use of boots was not sufficient to protect the miners from experiencing slips and falls. While miners' cautionary gait elicited significantly high physical exertion levels (as reflected by increased RPE levels) during walking on the firm-slippery surface and boot footwear condition, it was not successful in minimizing slips/falls (compared to other surface and footwear conditions).

Carrying a weight was also interacted with type of footwear worn for the PSOS outcome ($p<0.04$). A firm-slippery surface induced the greatest PSOS and more than would be expected from an additive model when not carrying a weight.

Table 57. Main Effects, Significant Covariates and Interactions for Gait PSOS.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	89.98	**0.0001**
Surface	2	46	168.93	**0.0001**
Lighting	1	23	0.66	0.4263
Footwear	1	23	58.41	**0.0001**
Weight*Surface	2	46	3.71	**0.032**
Surface*Footwear	2	46	44.08	**0.0001**

Table 58. Main Effects, Significant Covariates and Interactions for Gait RPE.

Effect	Numerator DF	Denominator DF	F-Value	p-value
Weight	1	23	236.95	**0.0001**
Surface	2	46	14.57	**0.0001**
Lighting	1	23	0.06	0.8143
Footwear	1	23	20.19	**0.0002**
Surface*Footwear	2	46	14.27	**0.0001**

D.9.d. Slips and Falls during dynamic balance tasks

See Tables 59-60 for Slips and falls results. In the following the table of significant findings for main effect, cofactors and interactions is shown. The remaining tables and figures of least squares means of the significant findings are given in Appendix Y.

The type of surface was found to be significantly related to both slips ($p<0.0001$) and falls ($p<0.03$). A slip was much more likely on the firm-slippery surface than on either the firm-dry surface (OR=66.4) or the uneven-dry surface (OR=25.0). Similarly, falls occurred much more often on a firm-slippery surface than either a firm-dry (OR=19.0) or uneven-dry (OR=17.5) surface. Carrying a weight was associated with an increased probability of slip (p<0.004, OR=2.0). Wearing a rubber boot lead to an increased probability of fall (p<0.02, OR=5.7). Lighting was not associated with either slip or fall occurrences. See Appendix U for frequency of slips/falls.

Table 59. GENMOD procedure for Observed Slip during dynamic balance tasks.

Source	DF	Chi-Square	Pr>ChiSq
Weight	1	6.23	**0.0125**
Surface	2	22.87	**0.0001**
Lighting	1	0.3	0.5853
Footwear	1	2.43	0.1192

Table 60. GENMOD procedure for Observed Fall during dynamic balance tasks.

Source	DF	Chi-Square	Pr>ChiSq
Weight	1	1.01	0.3142
Surface	2	7.06	**0.029**
Lighting	1	0	0.9710
Footwear	1	5.99	**0.014**

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APPENDIX A

Health Survey Questionnaire

HEALTH SURVEY QUESTIONNAIRE

*If you have any questions about this form or other study information, please call Terry toll free at (877)735-2378. All information is kept CONFIDENTIAL

NAME:______________________________ DATE:______________________ ID:____________

Address:__________________________________ State:_________ Zip code:________

Phone number:___________________________ BIRTHDATE: ____________________

HAVE YOU EVER WORKED IN COAL MINES? (circle answer) **YES** **NO**

A. IF YES, HOW LONG WERE YOU/HAVE YOU BEEN A COAL MINER? ____ **(YEARS/MONTHS)**

B. WAS THE LAST MINE YOU WORKED AT (circle answer):
1. LOW SEAM 2. HIGH 3. ABOVE GROUND/STRIP?

ARE YOU CURRENTLY EXPOSED TO ANY OF THE FOLLOWING ON YOUR JOB? (circle all that apply)

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

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

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

HOBBIES (circle all which apply):

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

MEDICAL CONDITIONS (list all):____

____

CURRENT MEDICATIONS:

	Name of Medication	Since When	How Much?	How Often?
Prescr-iption				

Non-Prescription *examples* *cold remedy vitamins minor pain medications and others*	Name of Medication	How Much?	How Often?

ALCOHOL CONSUMPTION:

Do you now drink alcoholic beverages? (circle one) Yes No

How old were you when you first started drinking alcoholic beverages? ________ years

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

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

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

Kind of alcoholic beverage normally consumed (please circle number):

1. Beer
2. Wine
3. Spirits
4. Mixed

Amount of alcohol consumed at each setting (enter number of drinks): _______

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.

PRESENT OR PAST PROBLEMS:	in the past	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 (vertigo)	Y / N	Y / N	________
Chronic or recurring light-headedness (sensation of fainting)	Y / N	Y / N	________
Meniere's disease	Y / N	Y / N	________
Problems with maintaining balance (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, or asthma with exercise)	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(hypertension)	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	________
Depression or treatment for depression	Y / N	Y / N	________
Chronic foot or leg disability	Y / N	Y / N	________
Diabetes mellitus (sugar diabetes)	Y / N	Y / N	________

PRESENT OR PAST PROBLEMS:	in the past	CURRENT	MONTH/YEAR LAST EPISODE
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	________
Osteoporosis of the bones	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? ________

Do you have any fear of falling again? Y / N

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/hearing 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 all that apply:
0.None 1.walking 2.jogging 3. bicycling 4. swimming

5. weight lifting 6. racket sports 7. (specify)________

Enter the number of hours per week that you exercise: ________

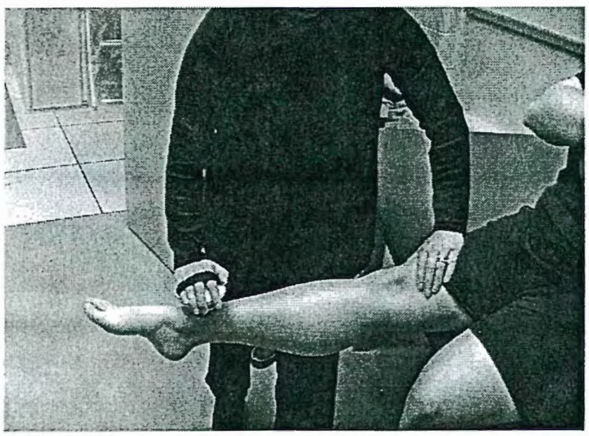
APPENDIX B

Lower Limb Strength Testing Protocol and datasheet

Lower Limb Strength Testing for Coal Miners Screening

Lower limb muscle strength is measured using the MicroFIT2 manual muscle testing unit (Hoggan Health Industries, Draper, UT). Similar testing protocols have been used in other studies, which will allow direct strength measurements comparisons[1]. Maximum isometric muscle strength will be measured in the quadriceps, hamstrings, ankle plantar flexors, and ankle dorsiflexor muscle groups bilaterally. Subjects will be asked to contract each muscle group for a period of 10 seconds against the tester's resistance. Three trials will be recorded for each muscle group and averaged. Measurements will be taken with the MicroFIT2 set at the "High Threshold" test range.

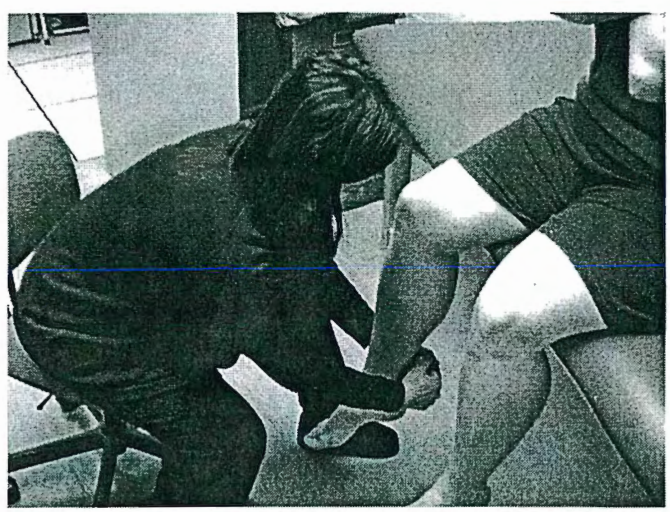
Quadriceps:



The subject will be sitting on the exam table with their test knee slightly flexed from the full knee extension position (approximately 5° knee flexion). Have the subject cross their arms in front of their chest during testing. The MicroFIT2 is placed on the anterior aspect of the tibia, just proximal to the level of the lateral malleolus with the curved transducer pad for comfort. The tester will stand by the subject's side with one hand on the thigh above the test knee to stabilize the leg and the other hand holding the MicroFIT2 in position. The subject will be asked to straighten the knee while the tester attempts to flex the knee against the subject's resistance for 10 seconds.

Hamstrings:

The subject will be sitting on the exam table with both knees at 90° and their arms crossed in front of their chest. The MicroFIT2 is placed on the posterior aspect of the ankle just proximal to the level of the lateral malleolus with the curved transducer pad. The tester will sit in front of the subject with both hands on the MicroFIT2. The subject will be asked to bend their maintain their knee while the tester attempts to extend the subject's knee.



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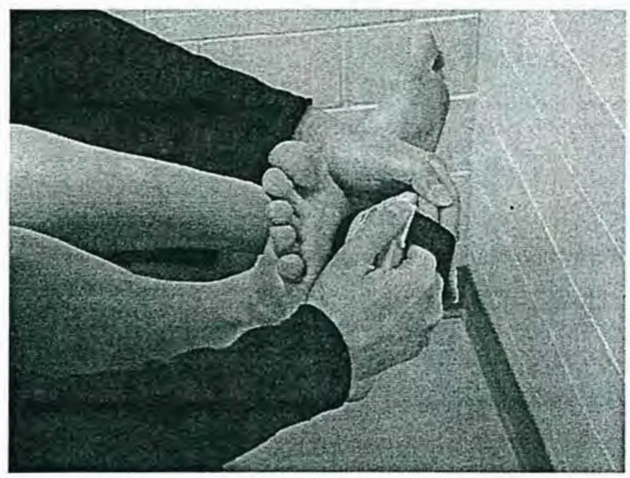
[1] Andrews, A.W., Thomas, M.W. and Bohannon, R.W. (1996). Normative Values for Isometric Muscle Force Measurements Obtained with Hand-held Dynamomters. Physical Therapy, 76: 248-259.

Ankle Dorsiflexors:

The subject will be seated in the long sitting position with their legs fully supported by the exam table with their shoes off. The subject will be asked to relax the test ankle in the plantarflexed position. The MicroFIT2 will be placed just proximal to the MTP joints on the dorsal surface of the foot with the flat transducer pad. The tester will stand facing the subject with both hands on the MicroFIT2. Subjects will be asked to pull their foot up while the tester attempts to plantarflex the ankle.

Ankle Plantarflexors:

The subject will be seated in the long sitting position with their legs fully supported by the exam table with their shoes off. The subject will position their test ankle in the neutral position. The MicroFIT2 will be placed just proximal to the MTP joints on the ball of the foot with the flat transducer pad. The tester will stand facing away from the subject with both hands on the MicroFIT2. Subjects will be asked to point their toes down while the tester attempts to dorsiflex the ankle.



Lower Limb Muscle Strength Testing Procedures

1. Turn MicroFIT2 on. Press the Threshold button until the "H" is displayed on the "Duration/Secs" display window.
2. Attach the appropriate transducer pad for the muscle group being tested.
3. Instruct the subject to assume the subject and initial joint positions.
4. Place the MicroFET2 in the correct position.
5. Assume the examiner position to help stabilize the subject during testing.
6. Ask the subject to maintain the initial joint position while the examiner attempts to overpower the subject's ability to maintain that position for 10 seconds (as displayed on the "Duration/Secs" window).
7. Allow the subject to rest for about 10 seconds between contractions.
8. Record the peak force for 3 trials for each muscle group bilaterally.
9. When possible, alternate sides and muscle groups to allow sufficient rest time without unnecessary repositioning the subject (ie. Test in the following order: Right Quads, Left Quads, Right Hamstrings, Left Hamstrings, Right Dorsiflexors, Left Dorsiflexors, Right Plantarflexors, Left Plantarflexors)

Muscle Group	Subject Position	Initial Joint Position	Examiner Position	MicroFET2 position	Instructions for Subjects	Transducer Pad
Quadriceps	Sitting at side of exam table with arms crossed in front of chest	Knee bent slightly from full extension (~ 5° knee flexion)	Standing with one hand on subject's thigh above the knee and other hand holding the MicroFET2	Anterior aspect of tibia just proximal to the level of the lateral malleolus	"Straighten your knee"	Curved
Hamstrings	Sitting at side of exam table with arms crossed in front of chest	Knee at 90°	Sitting in front of subject's ankle with both hands on the MicroFET2	Posterior aspect of tibia just proximal to the level of the lateral malleolus	"Bend your knee"	Curved
Ankle Dorsiflexors	Long sitting, legs supported by exam table, ankle off edge & shoes off	Ankle in relaxed plantarflexed position	Standing by subject's side facing the subject with both hands on the MicroFET2	Dorsal surface of the foot just proximal to the MTP joints	"Pull your foot and toes up towards your face"	Flat
Ankle Plantarflexors	Long sitting, legs supported by exam table, ankle off edge & shoes off	Ankle in neutral position	Standing by subject's side away from the subject with both hands on the MicroFET2	The ball of the foot just proximal to the MTP joints	"Point your toes and foot"	Flat

Miners Strength Testing Data Sheet

Name: ______________________________ **Subject ID:**__________ **Test Code:**__________

Date of Testing: _____________ **Examiner:** ________________________

Hand Dominance: R L

Maximal Static Muscle Strength (10 second duration) (lbs.)

Muscle Group	**Subject Instructions**	**Trial 1**	**Trial 2**	**Trial 3**	**Comments**
Right Quads	"Straighten your knee"				
Left Quads	"Straighten your knee"				
Right Hamstrings	"Bend your knee"				
Left Hamstrings	"Bend your knee"				
Right Dorsiflexors	"Pull your foot & toes up towards your nose"				
Left Dorsiflexors	"Pull your foot & toes up towards your nose"				
Right Plantarflexors	"Point your toes & foot down"				
Left Plantarflexors	"Point your toes & foot down"				

Testing code: 0 - Subject was resting, not work or testing session
1 - Testing done at least 2 hours after working or testing session

APPENDIX C

Snellen chart for vision testing and datasheet

MINING VISION TESTING DATASHEET

Name:______________________________ Subject ID:______________ Date:_____________

Snellen Equivalent __________________

Contact Lenses? Yes No

Bifocals? Yes No

Trifocals? Yes No

Last Eye Exam by Doctor?_____________

Change Rx? Yes No

Dominant Eye? Right Left

Tester? ________________

Comments?____

____

A

36

D F

24

H Z P

18

T X U D

12

Z A D N H

9

P N T U H X

6

U A Z N F D T

5

N P H T A F X U

4

X D F H P T Z A N

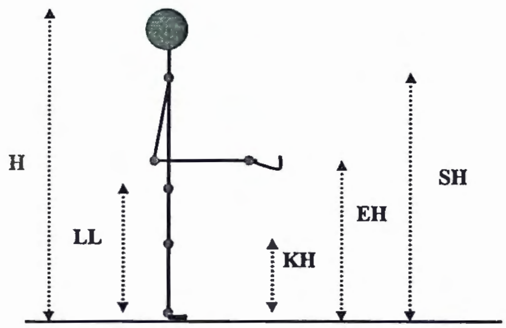
3

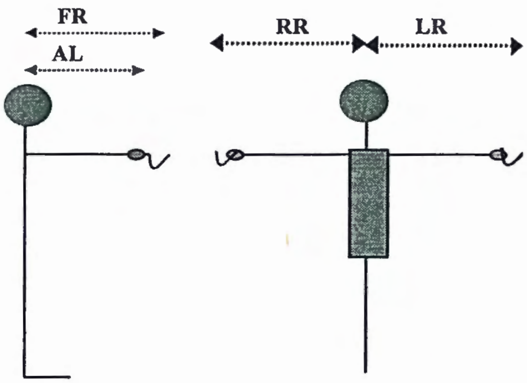
F A X T D N H U P Z

APPENDIX D

Anthropometric datasheet

Anthropometric & Demographic Measurements (Modified 10-30-01)





A. Identification

A1. Subject ID: ________

A2. Date of Visit: ________ (mm/dd/yy)

A3. Gender: ________ (M/F)

A4. DOB: ________ (mm/dd/yy)

B. Gross Physical Measurements

B1. Height: ________ (cm)(*H*)

B2. Weight: ________ (kg)

B3. Shoe Size: ________

B4. Right Foot Length: ________ (cm)

B5. Right Foot Width: ________ (cm)

B6. Left Foot Length: ________ (cm)

B7. Left Foot Width: ________ (cm)

C. Segmental Measurements

C1. Leg Length: ________ (cm)(*LL*)

C2. Arm Length: ________ (cm)(*AL*)

C3. Trunk circumference: ________ (cm)

C4. Knee Height: ________ (cm)(*KH*)

C5. Shoulder Height: ________ (cm)(*SH*)

C6. Elbow Height: ________ (cm)(*EH*)

D. Functional Reach Distances

D1. Forward Functional Reach: ________ (cm)(*FR*)

D2. Left Arm Lateral Functional Reach: ________ (cm)(*LR*)

D3. Right Arm Lateral Functional Reach: ________ (cm)(*RR*)

E. Reaction Time

E1. Arm/Foot Tested: ________ (R/L)

E2A. Arm Reaction Time 1: ________

E2B. Arm Reaction Time 2: ________

E2C. Arm Reaction Time 3: ________

E3A Foot Reaction Time 1 ________

E3B. Foot Reaction Time 2 ________

E3C. Foot Reaction Time 3: ________

F. Living Arrangement(Circle One):

F1 = Alone
F2 = With spouse or partner
F3 = With child or other family
F4 = Other

Race(Circle One):

G1 = White
G2 = Black/African American
G3 = Hispanic
G4 = Native American or Alaskan Native
G5 = Asian or Pacific Islander
G6 = Other

Education(Circle One):

H1 = Less than 12th
H2 = High school grad
H3 = Undergraduate degree
H4 = Graduate degree
H5 = Some college

APPENDIX E

COF Software Description and Protocol

COF Program Description

The COF program has been developed to communicate with and control A/D board and platforms and handle the data acquisition process including channel monitoring, calibration, data collection, calculation and plotting, etc. It is also designed to be easily scalable for multiple platforms and different A/D boards.

Development software and platform:
Visual C++ 6.0 under Windows NT/98

Hardware requirement:
Pentium 300MHz, memory 32M, 64M recommended, CD-ROM driver.

Installation:
1) Install DTx-EZ before install the driver is required by Data Transition Inc. If you have installed the A/D board driver without installing DTx-EZ ActiveX controls, you have to uninstall the driver first and install DTx-EZ firstly.

2) Copy all the files in install-disk to a same directory. Click b2k_beta_1.exe and you can begin to use COF program. It is preferred that all the files are saved and run in the same directory.

3) When the program starts, it uses the Plate 2 as default plate. If other plates are required, add new plate before the test. In any case, double-check the specifications of the force plate such as c-value.

COF Testing Procedures

One method to measure the coefficient of friction (COF) between a shoe's surface and the ground surface is by using a force plate to measure the horizontal and vertical forces exerted by the shoe as the shoe is dragged by a motor at a constant speed across a surface.

1. **Equipment Setup:**
   - In the Tribology Lab (Room 324), the computer by the force plate has been set up to control the motor and the UC #6 computer (one with the A/D board) controls the data collection program. Testing has been done using the TLC Gait Study plate and one amplifier.
   - The shoe is attached to the motor using flexible wire taped around the shoe and tied firmly to the motor. Make sure to tape the wire around the shoe without taping near the sole surface. The wire should be tied firmly around the rotary motor and tightened with the screw and allen key. When the shoe is attached to the motor, make sure the motor is positioned so that it pulls the shoe parallel to the force plate surface. During testing, the motor must be stabilized with heavy weights to minimize any movement during testing. Any inconsistencies with the direction of pull or movement of the motor may affect the COF results observed.
   - To control the motor, turn the computer which controls the PC21 indexer/motor on at the surge bar and type **C:\COF\PC21TERM** and press "enter" to begin the program.
     Type in the Board Address: **768**
     Type in the following commands:
       - **MC** (set to continuous mode)
       - **A100** (set acceleration to 100 rps^2)
       - **V10** (set velocity to 10 rps)
       - **G** (do not press the "enter" key after **G** until you are ready to start the motor)

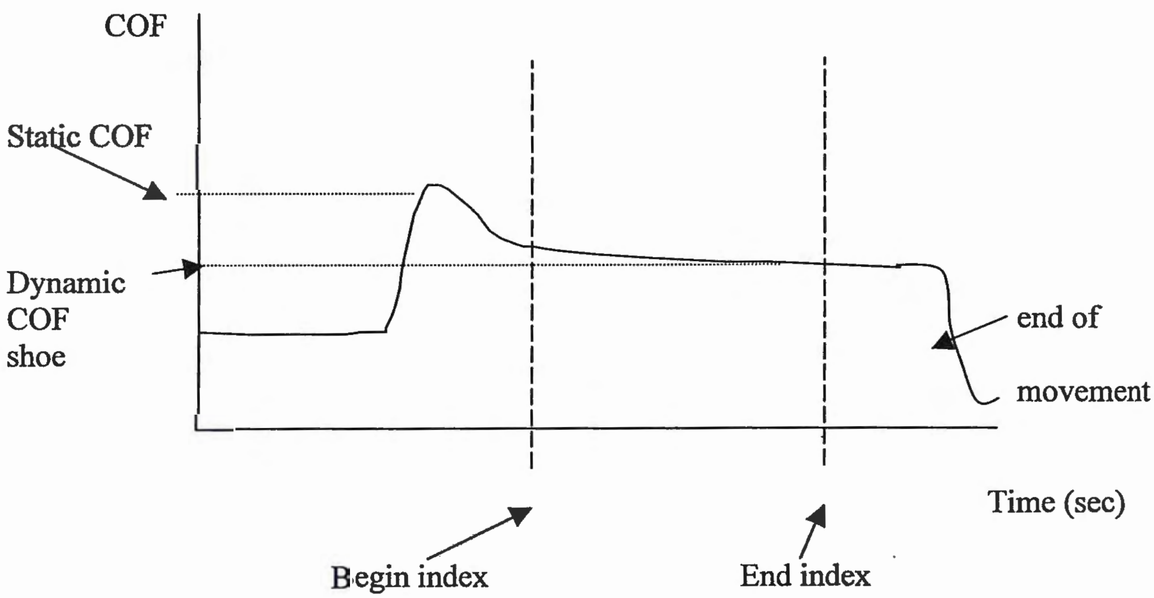
     Press the "F8" key to stop the motor
     These parameters will generate a constant horizontal force that pulls the test shoe at a velocity of 20 cm/sec.
   - Test to make sure that the motor is rotating in the appropriate direction and that there is enough wire available to place the shoe diagonally at the starting position of the plate with minimal tension on the wire. If you need to change the moving direction of the motor, type **H+** (to move clockwise) or **H-** (to move counter-clockwise) in the command line. Consult the menu for additional commands.
   - To attach the aluminum plates on the force plate for testing, one surface of the aluminum plate must be attached to a magnet. Magnets often have an offset and must be carefully cut to ensure that it is secured in the proper orientation during testing.
   -
   - When testing shoes on oily surfaces, be sure to use the plate labeled "OILY". This will ensure that the plate for use on dry surfaces remains free of contaminants which may affect your COF results.

- When calibrating the force plate, attach a small piece of acetate to the middle of the plate to protect it from scratches during calibration. First, zero the plate and calibrate with the acetate on. When calibration has been completed, re-take the baseline without the acetate. It is not necessary to recalibrate with the known weight after removing the acetate.

2. **Running the COF program:**
   - The new COF program saves output files in the same directory it is located in. Be sure to copy and run the program in the same directory you want to keep your data in.
   - When the program opens, click on the appropriate A/D board (DT2801 for the UC #6 computer) and force plate (plate #1 for the TLC Gait plate) and click on "accept plate".
   - Click "Start" to open the program and click on "Step One" to begin. In the Monitoring Module, click "Start" to monitor the amplifier channels. Each channel should be as close to 0 bits as possible (+/-20 bits). Use a small screwdriver to balance the amplifier readings if they are beyond this range. Monitor the channels by turning the amplifier screws until the light indicator for each channel is off. Click OK when all channels are in the appropriate range.
   - In the main menu, click on "Step Two" to calibrate the plate. The sampling frequency should be set at 30 samples/sec and the duration time should be 3.00 seconds. Be sure these are the parameters you wish to collect data with. If you need to change these parameters for your data collection at a later time, you must return to "Step Two" and recalibrate. Enter the weight of the calibration weight that you are using. Currently, the 8.2 lbs. aluminum block has been used for calibration. With only the acetate taped onto the surface of the plate, click "Read Baseline" to zero the plate. Next, place the calibration weight over the acetate as close to the center of the plate as possible. Wait a few seconds for the weight to stabilize and click the "Calibration" button. Weight measurements should have an error of less than 2%. Repeat the calibration if necessary to ensure accuracy. Record the percentage error readings on your datasheet. Remove the acetate from the force plate and click "Read Baseline" again to re-zero the plate. Since you have already calibrated, you will not need to recalibrate after the acetate has been removed. Click "OK" to begin collecting data.
   - Place the shoe diagonally in the start position on the plate. Ensure that the wire which attaches the shoe to the motor has minimal tension on it without the wire touching the force plate. The shoe must also be weighed down with a known weight. Currently, 6 Kg of lead shots are inserted into the shoe for testing. Next, go back to "Step One" to monitor the channels again. Fx and Fy should be less than +/- 20. If it is too high, move the shoe to reduce the wire tension.
   - Once the tension is correct and all the channels are in the appropriate range, have one person ready to run the motor and one to control the COF data collection program. Since the computer will collect 3 seconds of data but there is only sufficient space to pull the shoe for approximately 1 second, data collection must start before the motor begins to run. This will require careful coordination. The person running the data collection computer should give the cues "Ready, Set,

Begin". He/she must also tell the person controlling the motor to stop the motor before the shoe reaches the end of the force plate. The data collection person should first go to "Step Three" in the main menu and click the "Collecting Sample" button to start collecting data on the "Set" command. The person controlling the motor must wait for the "Begin" cue before starting the motor. Watch the shoe carefully during the trial for excess shoe wobble or the shoe being pulled too far off the plate. Before the shoe reaches the end of the plate, the motor should be stopped.

- When the data collection is finished, click "OK" and click the "Save Data into File" button to save the data into your directory as a *.raw file or the "Abandon the Data" button to repeat the trial. Always check your data by going to 'Step Four". Click the "Load File" button and type in the filename to load the raw file you have just collected. Once the file is loaded, click on the graph to see your COF results. The graph should resemble the following diagram:



- Static COF is the maximum horizontal force (as measured by the force plate) divided by the vertical force (determined by the weight of the shoe, lead shots used, and gravity). Usually, this is seen in the first initial peak of the graph just before the shoe is set into motion.
- Dynamic COF is the horizontal force over the vertical force when the shoe is traveling at a constant speed. This is calculated after the initial peak when the shoe first begins to move. The COF program will need to know when this occurs in order to calculate the dynamic COF accurately. To specify this area, you must click on the "BeginIndex" button and click on the graph where the initial peak drops and starts to become a straight line (see diagram). You must also click on the "EndIndex" button to specify the area on the graph where the

trial has ended and the shoe is near the end of the force plate. This will prevent any miscalculations which may result if any fluctuations occur because the shoe has traveled off the plate. After indexes are defined, click the "Calculate" button and record the dynamic and static COF results on your datasheet.

- To save your results, click the "Save File" button and save it as a *.out output file. Click "Save" and return to the main menu to collect other trials in the same manner.

3. **After Data Collection:**
   - Save and backup all files onto diskettes or Zip disks and clear the directory on the hard drive to conserve hard disk space.
   - Shut down the computer that runs the motor by pressing the "F10" key and turning off the computer power bar. Be sure to leave the amplifier on at all times by keeping it plugged into a separate outlet.
   - Close the COF program and shut down the data collection computer by going to the "Start" button on the menu bar and click on "Shut Down" then "OK". Wait until the computer shuts down and then turn the surge bar off.
   - Always clean the aluminum plates, shoes, and all other equipment thoroughly. Replace flooring and return all equipment to their proper locations.

APPENDIX F

Calculation of maximum weight limit for lifting bucket of bits

Calculation of maximum weight limit for lifting bucket of bits task using:
Revised NIOSH Lifting Equation

RWL = LC x HM x VM x DM x AM x FM x CM

Where:
LC = load constant
HM = horizontal multiplier
VM = vertical multiplier
DM = distance multiplier
AM = asymmetric multiplier
FM = frequency multiplier
CM = coupling multiplier

BUCKET

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (deg)		Frequency Rate	Duration (hrs)	Object Coupling
		Origin		Dest			Origin	Dest	lifts/min		
L (Avg)	L (Max)	H	V	H	V	D	A	A	F		C
8.8	8.8	19	0	19	32	32	0°	135°	0.5	< 1	Fair

RWL = 51 x 0.53 x 0.78 x 0.88 x 1.0 x 0.97 x 0.95
RWL = 17.10

APPENDIX G

Calculation of maximum weight limit for lifting cable

Calculation of maximum weight limit for lifting cable task using:
Revised NIOSH Lifting Equation

RWL = LC x HM x VM x DM x AM x FM x CM

Where:
LC = load constant
HM = horizontal multiplier
VM = vertical multiplier
DM = distance multiplier
AM = asymmetric multiplier
FM = frequency multiplier
CM = coupling multiplier

<u>CABLE</u>

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (deg)		Frequency Rate	Duration (hrs)	Object Coupling
		Origin		Dest			Origin	Dest	lifts/min		
L (Avg)	L (Max)	H	V	H	V	D	A	A	F		C
23.7	23.7	19	0	19	44	44	0°	90°	0.5	< 1	Fair

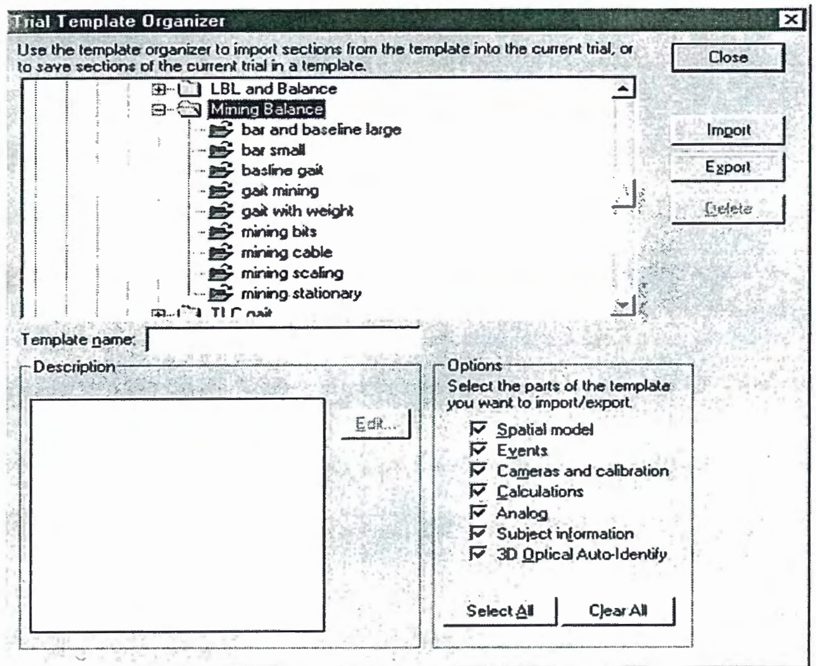
RWL = 51 x 0.53 x 0.78 x 0.86 x 1.0 x 0.97 x 0.95
RWL = 16.70

APPENDIX H

Motus templates for Static Balance and Gait Dynamic testing

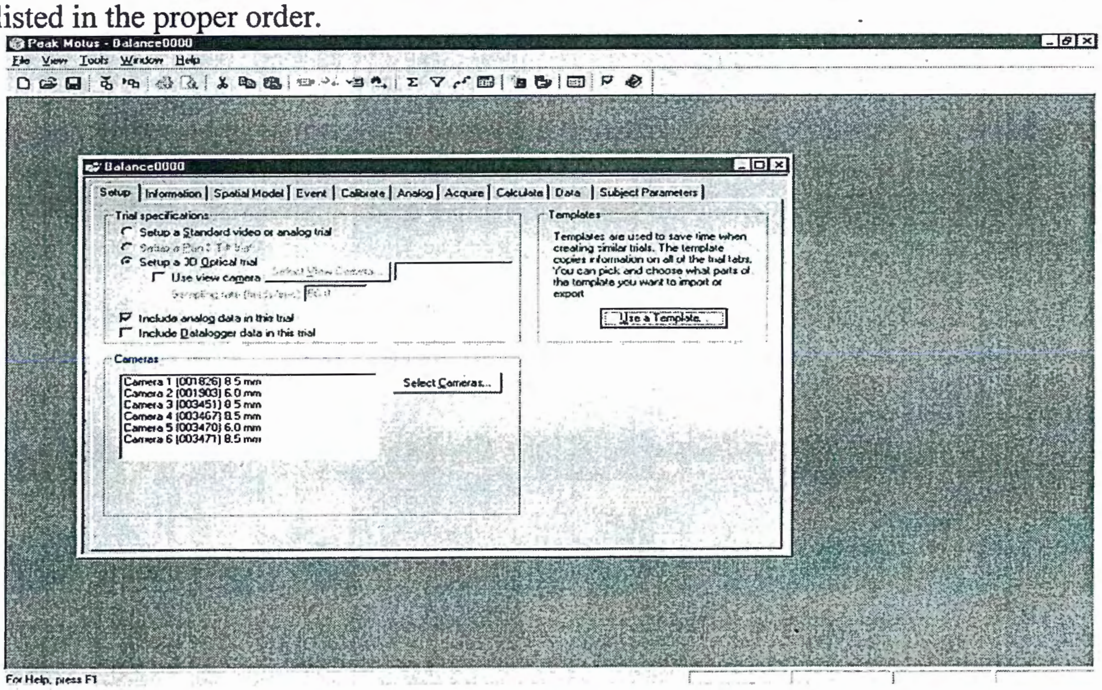
Motus Templates for Mining Study (2-19-03)

A Motus template is used for each trial. Each task (for balance) and with/without weight (for gait) trial has its corresponding template. Open the appropriate template in the Motus Template/Mining Balance directory from the Setup Tab for each trial.



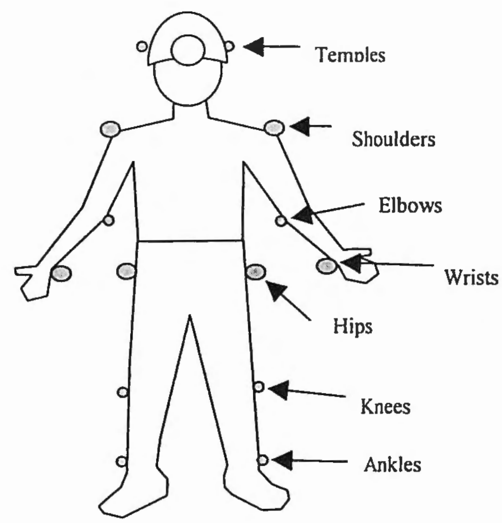
The following settings are in each template:

A. Setup: Setup a 3-D optical trial is marked. Analog data is included. Cameras used should be listed in the proper order.



B. Spatial Model
Balance:

Markers: The spatial model consists of 14 markers on the body, and 15-19 virtual points: 4 on the force plate, 6 for the feet, 4 for the ceiling and 1 or 3 for the center of mass (this depends of if the task requires an object), and 2 markers on the item (again, if the task requires an object).The markers on the body are: right ankle, right knee, right hip, right shoulder, right temporal, right elbow and right wrist; left ankle, left knee, left hip, left shoulder, left temporal, left elbow and left wrist.



The virtual points for all balance trials include (these are created with vectors of the global references *i*, *j*, and *k*):

center of mass (body – see COM Setup)
upper left of the large plate = (0)
lower left of the large plate = $(1.215 * i)$
lower right of the large plate = $(1.215 * i + 0.61 * j)$
upper right of the large plate = $(0.61 * j)$
upper right ceiling = $(0.61 * j + 1.12 * k)$
upper left ceiling = $(1.12 * k)$
lower right ceiling = $(1.215 * i + 0.61 * j + 1.12 * k)$
lower left ceiling = $(1.215 * i + 1.12 * k)$

The additional virtual points for the trials with an object:
center of mass of object (bucket of bits, cable or slabber bar) = (object top + object bottom)/2
center of mass of body + object =

$$[(COM_{body} * mass_{body}) + (COM_{object} * mass_{object})] / (mass_{body} + mass_{object})$$

Additional virtual points for the feet:
Due to difficulty digitizing the feet markers in Motus, we decided to eliminate the feet markers from the Balance Testing. We will estimate their location using measurements taken from the ankle to the respective points on the foot. These measurements can be used in equations to create virtual points for these markers. The measurements were taken on a pilot subject in size 10 leather boot. These were not included in the templates and are not used in the spatial model to calculate the COM, but can be added if the feet are desired for display purposes.

For the 1 knee posture with the left knee down, the feet had the following distances from the respective ankles: Note: these were measured with the left foot upright and the right foot was naturally splayed (rotated 10 degrees out).

Marker	x (cm) (global coordinate *i*)	y (cm) (global coordinate *j*)	z (cm) (global coordinate *z*)
Left Heel	5	7	11
Left 1st MTP	7	14	-14
Left 5th MTP	7	2	-12
Right Heel	6	-8	-4
Right 1st MTP	-15	-12	-5
Right 5th MTP	-16	3	-5

For the 2 knee posture, the feet had the following distances from the respective ankles:

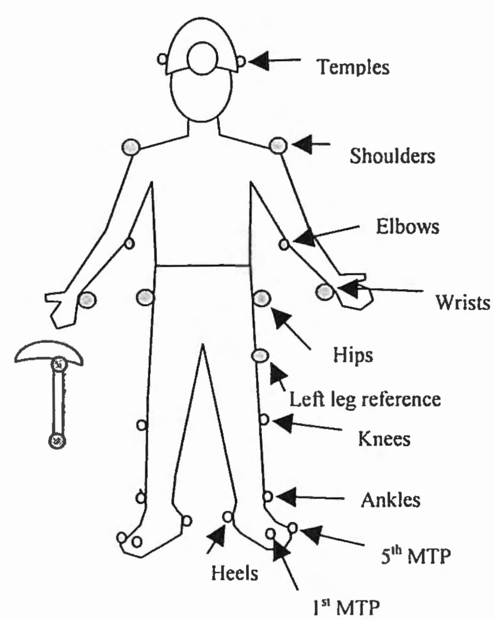
Marker	x (cm) (global coordinate *i*)	y (cm) (global coordinate *j*)	z (cm) (global coordinate *z*)
Left Heel	5	7	11
Left 1st MTP	7	14	-14
Left 5th MTP	7	2	-12
Right Heel	5	-7	11
Right 1st MTP	7	-14	-14
Right 5th MTP	7	-2	-12

Note: The right foot was taken from the left foot measurements for the one knee posture and the left remained the same. Since it is the relative distance of the ankle of the boot to each marker and each foot of the boot is the mirror image of the other, it was appropriate.

Segments:
Segments are connected between certain markers. These segments include the right medial (right 5th MTP and right heel), right lateral (right 1st MTP and right heel), right toes (right 1st MTP and right 5th MTP), right achilles (right heel and right ankle), right shank (right ankle and right knee), right thigh (right knee and right hip), pelvis (right hip and left hip), left thigh (left hip and left knee), left shank (left knee and left ankle), left achilles (left ankle and left heel), the left medial (left 5th MTP and left heel), left lateral (left 1st MTP and left heel), left toes (left 1st MTP and left 5th MTP), right forearm (right wrist and right elbow), right upper arm (right elbow and right shoulder), right head (right shoulder and right temporal), forehead (right temporal and left temporal), left head (left temporal and left shoulder), left upper arm (left shoulder and left elbow), left forearm (left elbow and left wrist), shoulders (left shoulder and right shoulder) left torso (left shoulder and left hip), right torso (right shoulder and right hip), right, left, front, back of large force plate and right, left front back of false ceiling. There are also segments for the bucket of bits, cable and slabber bar for those trials.

Gait:

Markers: The spatial model consists of 36 points including 21 markers on the body, 2 markers on the hammer and 13 virtual points. The 21 body markers are: Right 1st MTP, right 5th MTP, right heel, right ankle, right knee, right hip, right shoulder, right temporal, right elbow and right wrist; left 1st MTP, left 5th MTP, left heel, left ankle, left knee, left hip, left shoulder, left temporal, left elbow and left wrist. A left thigh reference marker is used to facilitate the auto path identify function. In addition, there are markers placed on the top and bottom of the hammer and on the weight (for the carrying weight trials only).



The virtual points included in both gait trials include (these are created with vectors of the global references *i*, *j*, and *k*):
center of mass = (body – calculated by Motus)
upper left of the large plate = (0)
lower left of the large plate = (1.215 * *i*)
lower right of the large plate = (1.215 * *i* + 0.61 * *j*)
upper right of the large plate = (0.61 * *j*)
upper left of the small plate = (0.685 * *j*)
lower left of the small plate = (0.51 * *i* + 0.685 * *i*)
lower right of the small plate = (0.51 * *i* + 1.15 * *j*)
upper right of the small plate= (1.15 * i)
upper right ceiling = (-0.5 * *i* + 1.15 * *j* + 1.12 * *k*)
upper left ceiling =(-0.5 * *i* + 1.12 * *k*)
lower right ceiling = (1.71 * *i* + 1.15 * *j* + 1.12 * *k*)
lower left ceiling = (1.71 * *i* + 1.12 * *k*)

The virtual points included in the weight trial include:
center of mass (weight) = (weight top + weight bottom)/2
center of mass of body + weight =

$$[(COM_{body} * mass_{body}) + (COM_{weight} * mass_{weight})]/ (mass_{body} + mass_{weight})]$$

Segments:
Segments are connected between certain markers. These segments include the right toe (right 1^{st} MTP and 5^{th} MTP), right lateral foot (right 5^{th} MTP and right heel), right medial foot (right 1^{st} MTP and right heel), right ankle (right heel and right ankle), right shank (right ankle and right knee), right thigh (right knee and right hip), pelvis (right hip and left hip), left thigh (left hip and left knee), left shank (left knee and left ankle), left ankle (left ankle and left heel), left medial foot (left heel and left 1^{st} MTP), left lateral foot (left heel and left 5^{th} MTP), left toe (left 1^{st} MTP and left 5^{th} MTP), right forearm (right wrist and right elbow), right upper arm (right elbow and right shoulder), right head (right shoulder and right temporal), forehead (right temporal and left temporal), left head (left temporal and left shoulder), left upper arm (left shoulder and left elbow), left forearm (left elbow and left wrist), shoulders (left shoulder and right shoulder) left torso (left shoulder and left hip), right torso (right shoulder and right hip), right of the plate, back of the plate, left of the plate and front of the plate (both large and small), the right, left, front, and back of the ceiling and the hammer.

Center of Mass (COM) Setup:

To appropriately add weight to the mining belt worn by subjects, it was assumed Miners would at least carry an emergency self-rescue breather and a large battery for the headlamp on their belts during all tasks (for both balance and gait trials). The belt with the self-rescue and lamp battery weighed 5.4 kg. This additional 5.4 kg load was distributed along the trunk and was accounted for in the kinematic spatial model. Using standard anthropometric data (Winter, 1990, see table A), the additional load was added to the trunk segment of our model and each body segment was be recalculated to reflect the additional weight and its segmental distribution. The balance trials add the feet mass to the shank since feet are not included in the spatial model and are shown in Table B. The gait segment mass percentage is shown in Table C.

Table A. Segmental mass calculations for standard male (Winter D.A: The biomechanics and motor control of human gait, New York: John Wiley and Sons, Inc., 1987).

Segment	Segment mass ratio	Total mass ratio (includes left and right)	Total distribution of mass based on standard 56.7 kg model (includes left and right)
Forearm & hand	0.022	0.044	2.5 kg
Upper arm	0.028	0.056	3.2 kg
Foot	0.0145	0.029	1.6 kg
Shank	0.0465	0.093	5.3 kg
Thigh	0.100	0.200	11.3 kg
Trunk	0.497	0.497	28.2 kg
Head & neck	0.081	0.081	4.6 kg

Table B. Segmental mass calculations for mining tasks with additional equipment weight (5.4 kg) added on belt for the Balance trials.

Segment	New mass based on standard 56.7kg model with additional 5.4 kg at trunk	% mass with additional 5.4 kg added to trunk (includes left & right)	New segmental % mass with additional 5.4 kg added to trunk
Forearm & hand	No change	4.0	2.0
Upper arm	No change	5.2	2.6
Shank +Foot	No change	11.2	5.6
Thigh	No change	18.0	9.0
Trunk	33.6 kg	54.2	54.2
Head & neck	No change	7.4	7.4

Table C. Segmental mass calculations for mining tasks with additional equipment weight (5.4 kg) added on belt for the Gait trials.

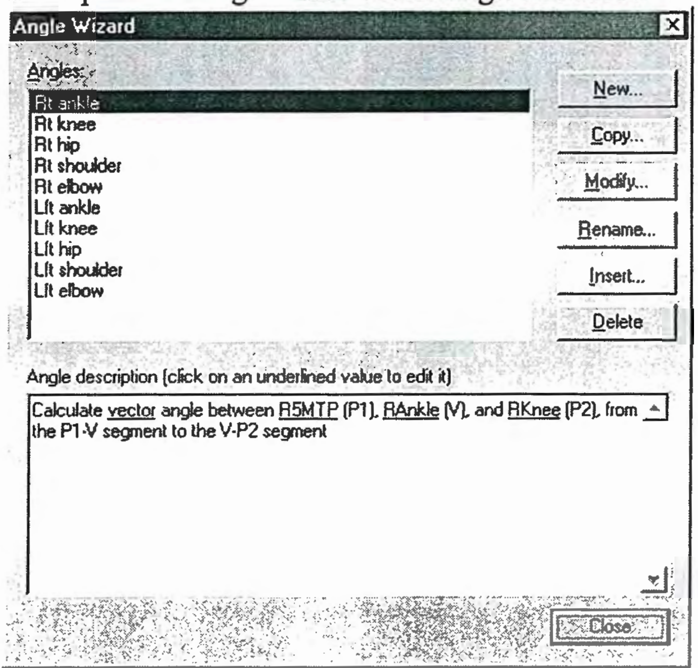
Segment	New mass based on standard 56.7kg model with additional 5.4 kg at trunk	% mass with additional 5.4 kg added to trunk (includes left & right)	New segmental % mass with additional 5.4 kg added to trunk
Forearm & hand	No change	4.0	2.0
Upper arm	No change	5.2	2.6
Foot	No change	2.6	1.3
Shank	No change	8.6	4.3
Thigh	No change	18.0	9.0
Trunk	33.6 kg	54.2	54.2
Head & neck	No change	7.4	7.4

Angles:

3-D joint angles were defined for the ankles, knees, hips, shoulders and elbows for each side of the body.

Angle	Type of Angle	P1	V	P2
Ankle	vector and anatomical 90	5th MTP	ankle	knee
Knee	vector and anatomical 180	ankle	knee	hip
Hip	vector and anatomical 180	knee	hip	shoulder
Shoulder	vector and anatomical 180	hip	shoulder	elbow
Elbow	vector and anatomical 180	shoulder	elbow	wrist

Example of the right ankle vector angle in Motus:



From this, the angles, angular velocities and accelerations are calculated. The following Figure describes how vector, anatomical 180 and anatomical 90 angles are calculated in Motus.

Motus32 Help

File Edit Bookmark Options Help

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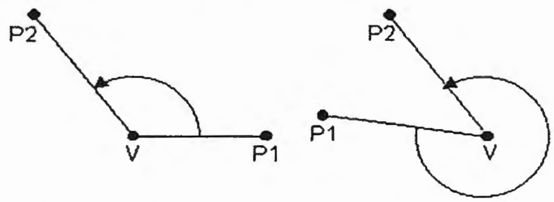
Display

How are angles calculated?

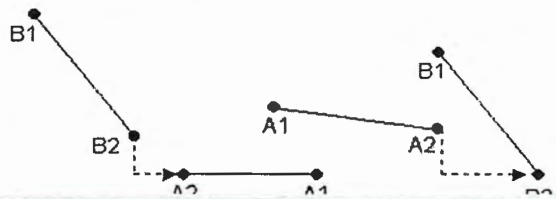
You can define calculations for either vector-based angles or anatomical-based angles.

Vector-based angle calculation

Referring to the figure below, the left angle displays the point positions in picture n and the right angle displays the point positions in picture n+1. The system calculates the angles as displayed, counter-clockwise with respect to the positive X-axis (to the right, in this case). If the difference between the right angle and the left angle is greater than 200, the system assumes that the P1-V segment has rotated passed the P2-V segment and a negative value will result (360-angle 2). Otherwise, the direct computation of the angle will be stored to the dataset.



For vector-based segmental angles, the system moves the segments so that points A2 and B2 become the vertex of a joint angle. The segmental angle is now calculated exactly like a joint angle.



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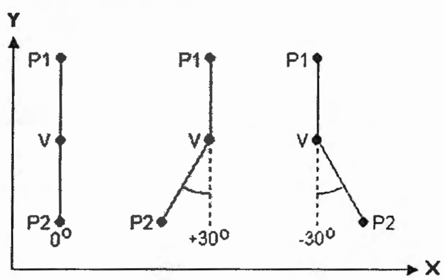
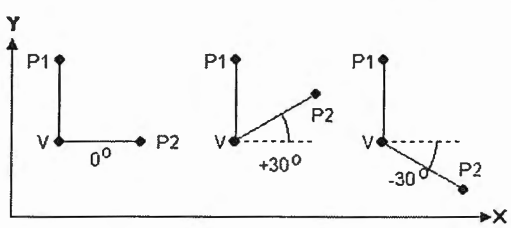
Anatomical-based angle calculation

Referring to the figure below, angles are calculated as viewed from the positive side of the orthogonal axis. Full extension, with three points aligned, calculates 0 degrees. Counter clockwise motion of the first segment with respect to the second segment increases the angle. Clockwise motion of the first segment with respect to the second segment decreases the angle. The angle can become negative in this case.



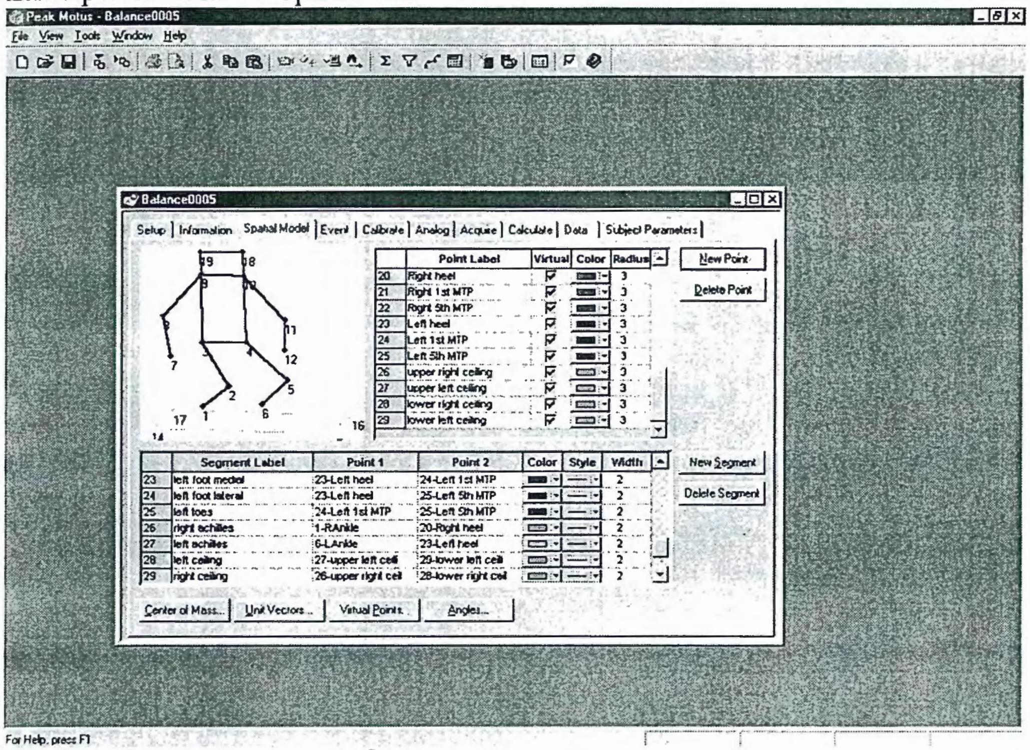
Anatomical-based angles of 90 degrees, as for the ankle, calculate a right angle at 0 degrees. Counter clockwise motion, or dorsi-flexion, increases the angle. Clockwise motion, or plantar flexion, decreases the angle.



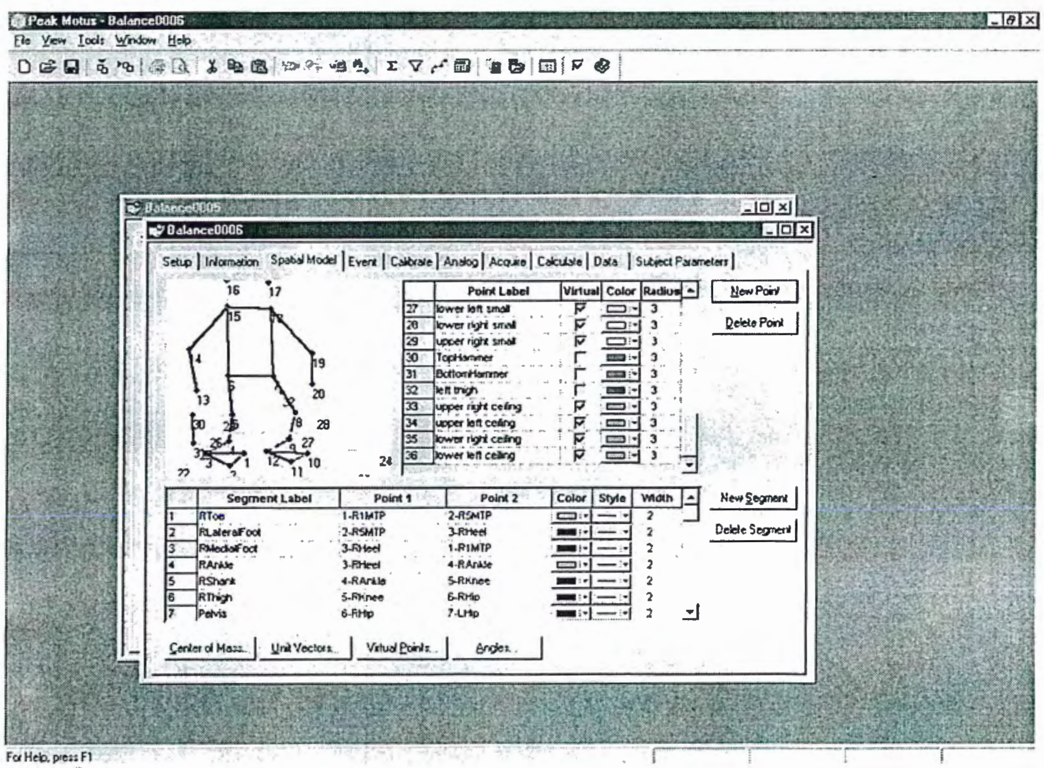
Related topics

- Define an angle between two adjoining segments (joint angle)
- Define an angle between the two non-adjoining segments (segmental angle)
- Define an angle between two adjoining segments projected onto a reference plane (projected joint angle)

Example of Balance Spatial Model:



Example of Gait Spatial Model

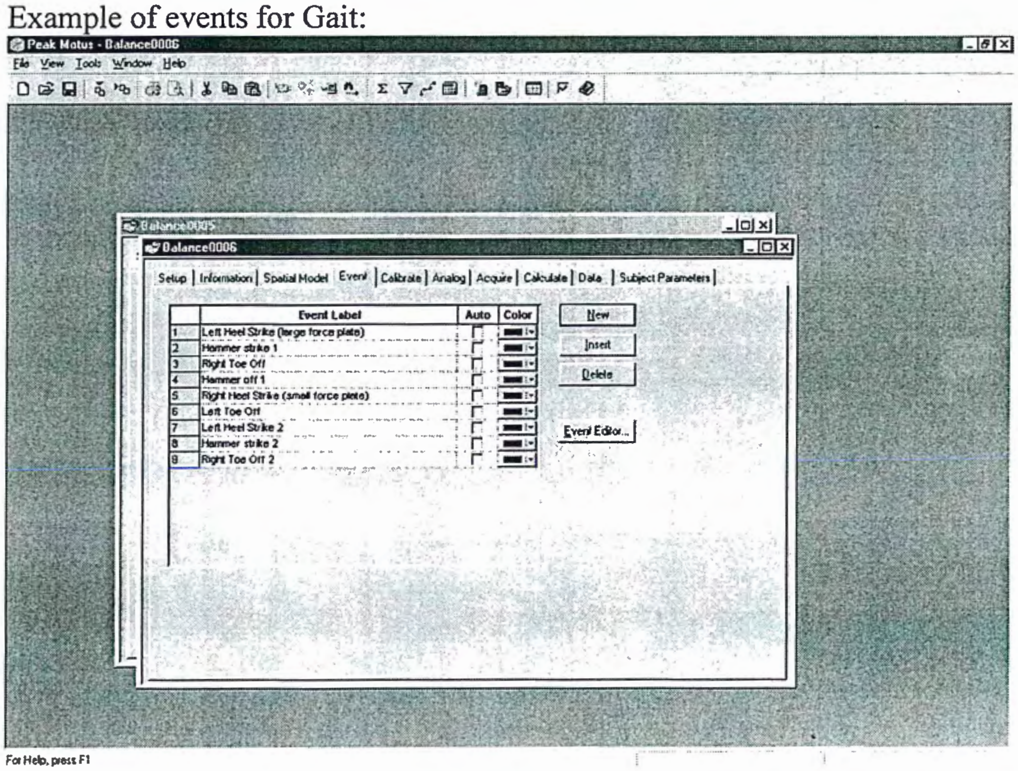


C. Events

There are different events for each task.

Task	Event
Stationary	(no events)
Lifting bucket of bits	Beginning of motion Contact with bucket Release of bucket End of motion
Lifting cable	Beginning of motion Contact with cable Release of cable End of motion
Scaling	Beginning of motion End of motion
Gait (both with and without weight)	Left heel strike 1 (large force plate) Hammer strike 1 Right toe off 1 Hammer off 1 Right heel strike (small force plate) Left toe off Left heel strike 2 Hammer strike 2
	Right toe off 2

Example of events for Gait:



D. Calibrate

Calibration will be completed for each session of data collection and will be shared for each session as a template named as "ID Cal date" in the working directory. Repeat the calibration if the standard deviation of the measured wand length exceeds 0.002 meter.

Length of wand=.91400

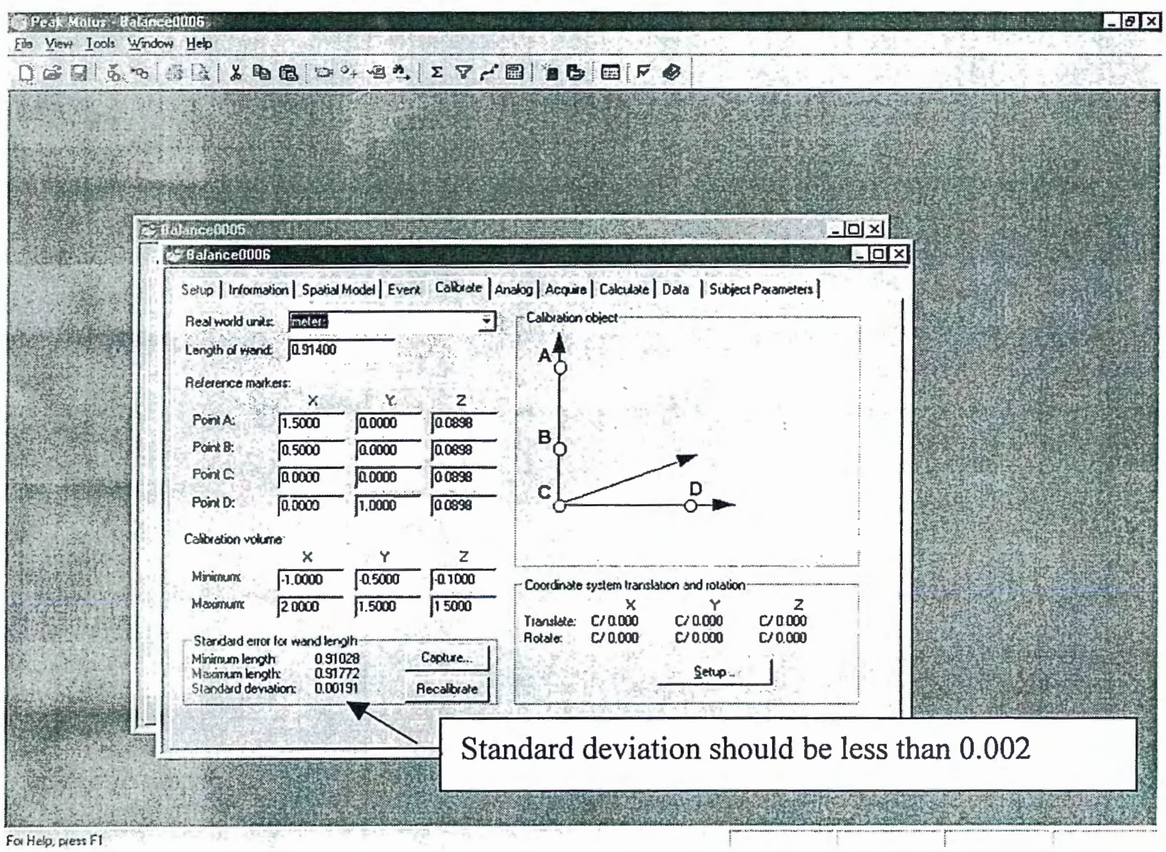
Calibration object and reference values:

	X	Y	Z
Point A	1.5000	0.0000	0.0898
Point B	0.5000	0.0000	0.0898
Point C	0.0000	0.0000	0.0898
Point D	0.0000	1.0000	0.0898

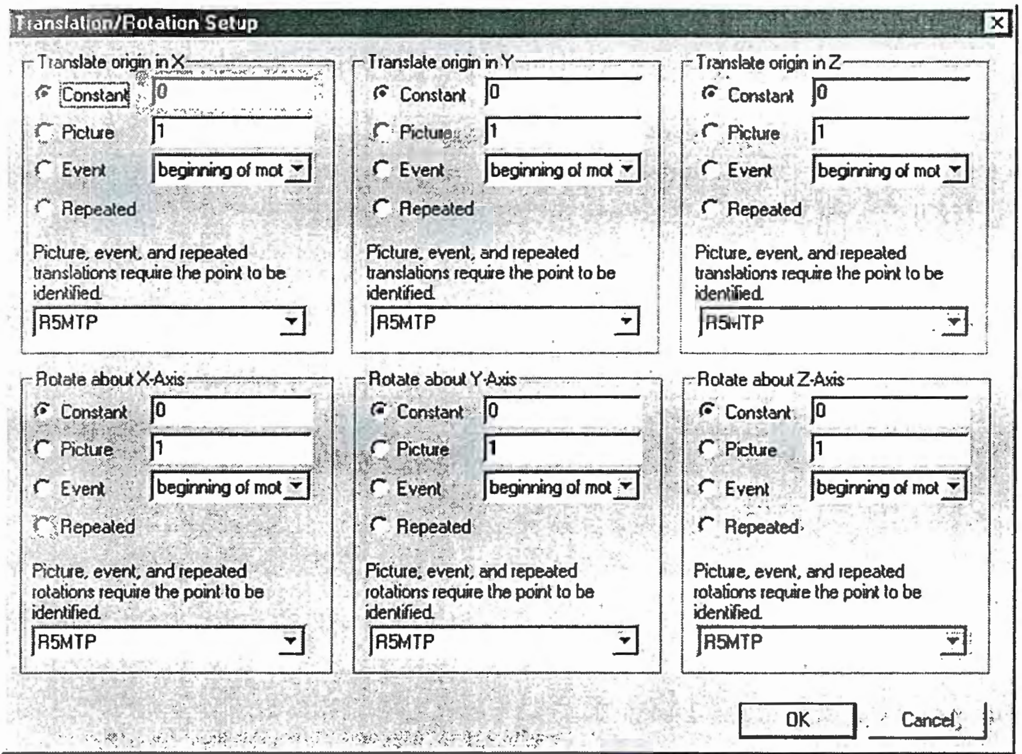
Calibration Volume:

	X	Y	Z
Minimum	-1.0000	-0.5000	-0.1000
Maximum	2.0000	1.5000	1.5000

Acceptable Standard Deviation: <.002



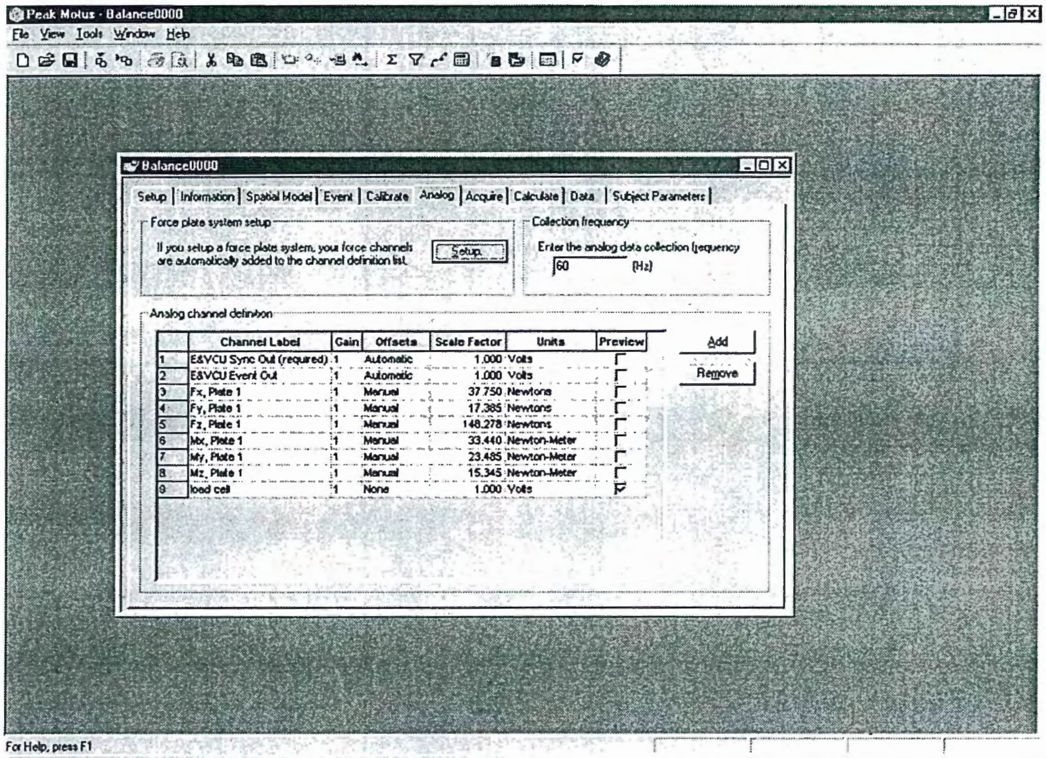
In set up, no translation or rotation.

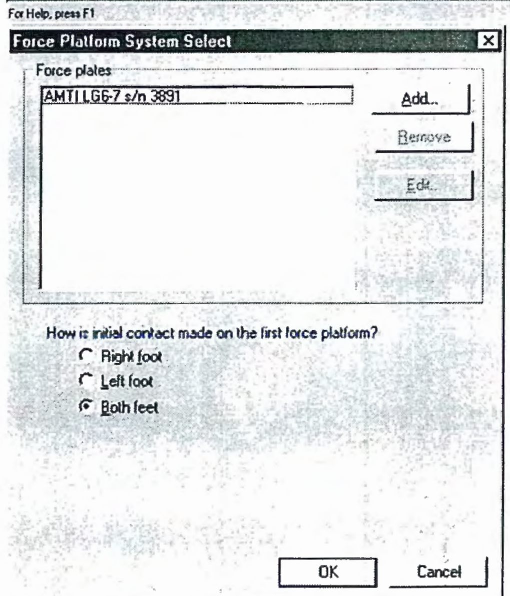


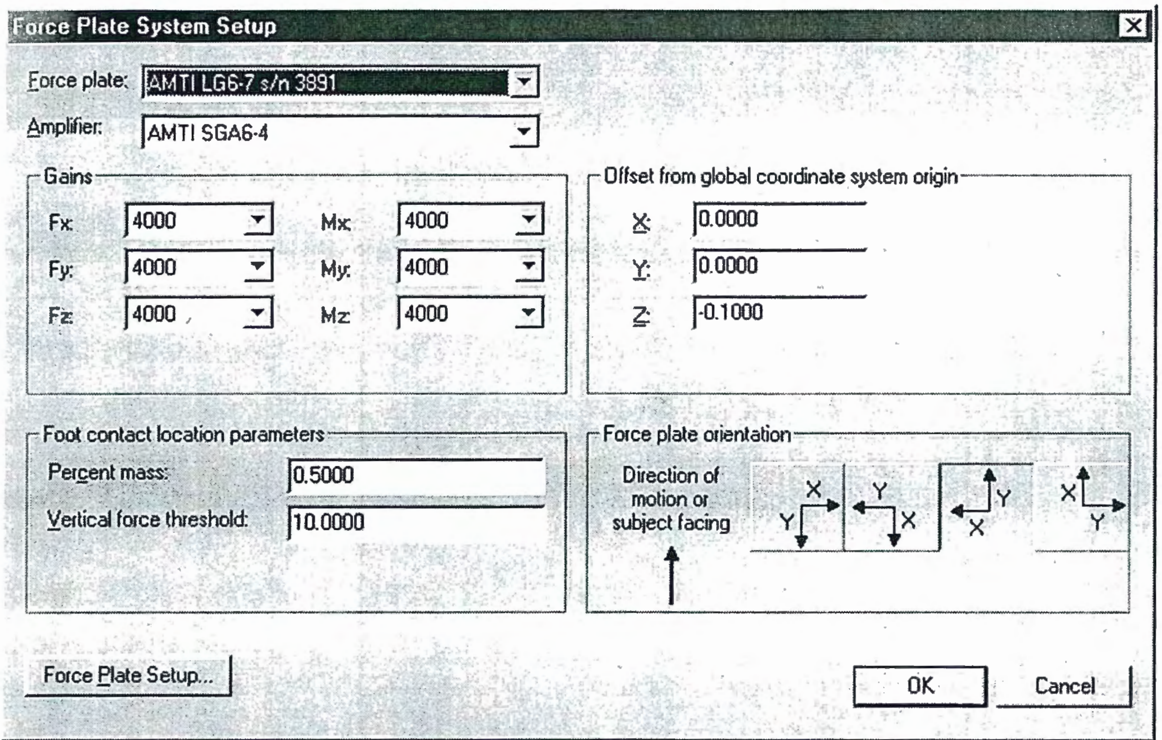
E. Analog

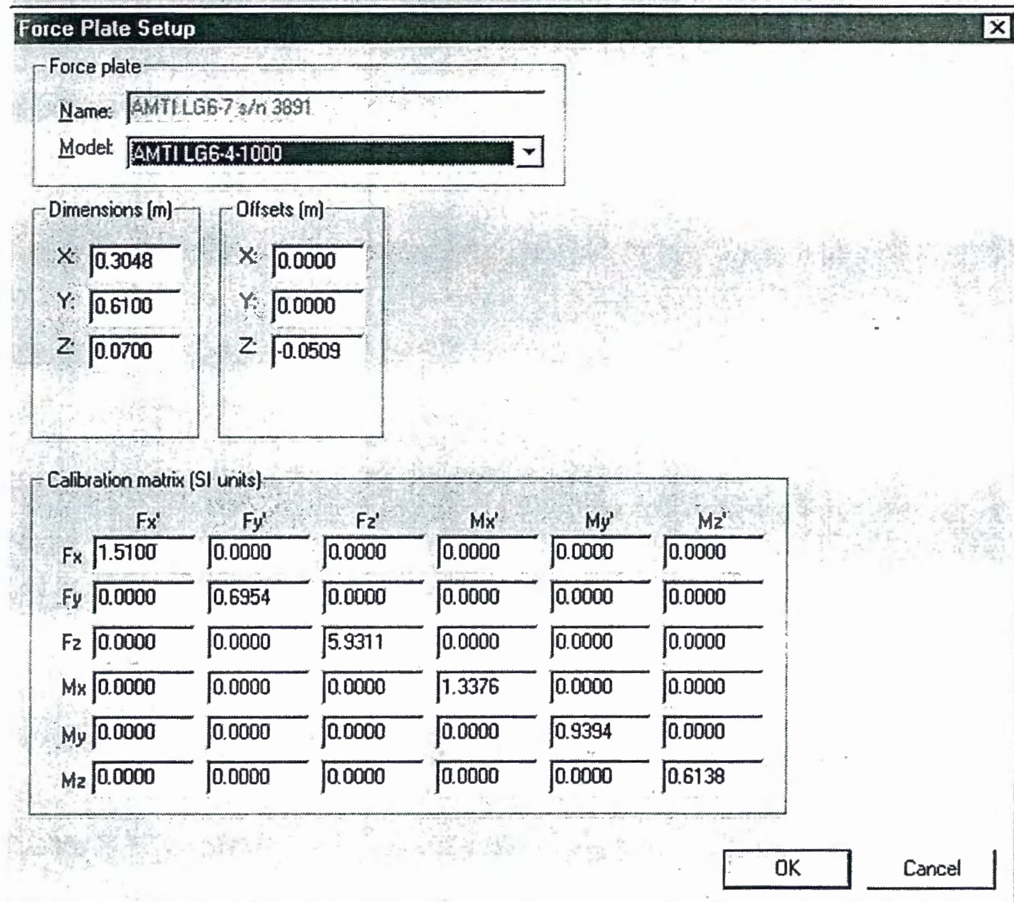
For the balance testing, Plate 1 is the large force platform and the collection rate is 60Hz. For the gait testing, Plate 1 is the large force platform and Plate 2 is the small force platform and the collection rate is 600 Hz. Also, for the scaling task, the load is added as a channel.

Example of balance analog setup for scaling task:

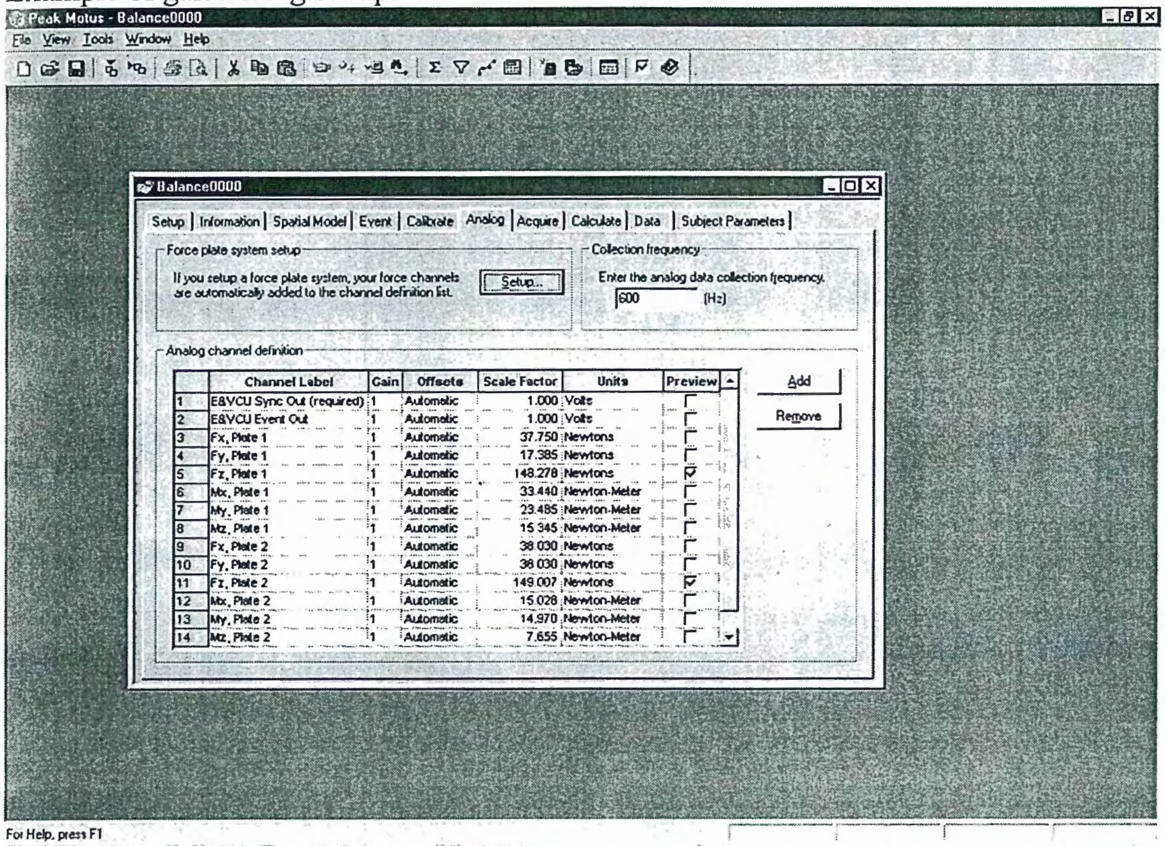


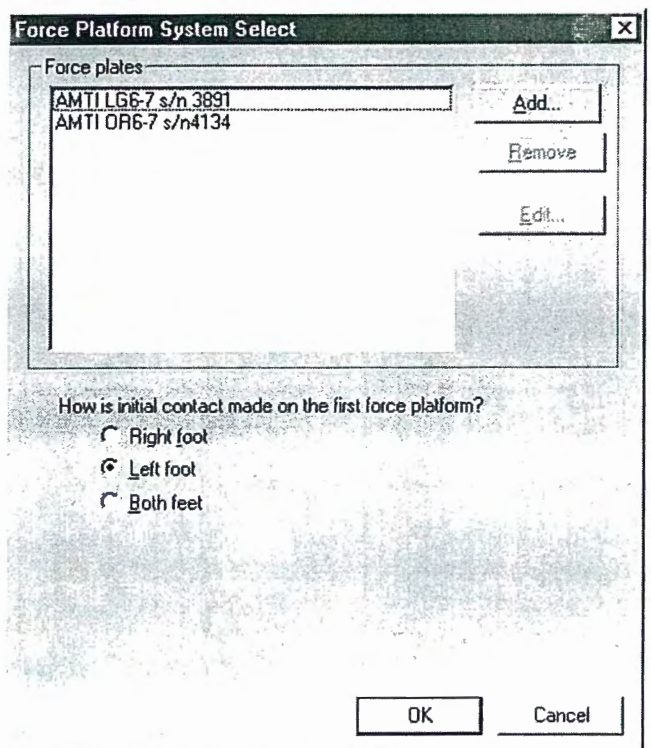



Force Plate System Setup
Force plate: AMTI LG6-7 s/n 3891
Amplifier: AMTI SGA6-4
Gains
Fx: 4000
Fy: 4000
Fz: 4000
Mx: 4000
My: 4000
Mz: 4000
Offset from global coordinate system origin
X: 0.0000
Y: 0.0000
Z: -0.1000
Foot contact location parameters
Percent mass: 0.5000
Vertical force threshold: 10.0000
Force plate orientation
Direction of motion or subject facing
X Y
Y X
Y X
X Y
Force Plate Setup...
OK
Cancel

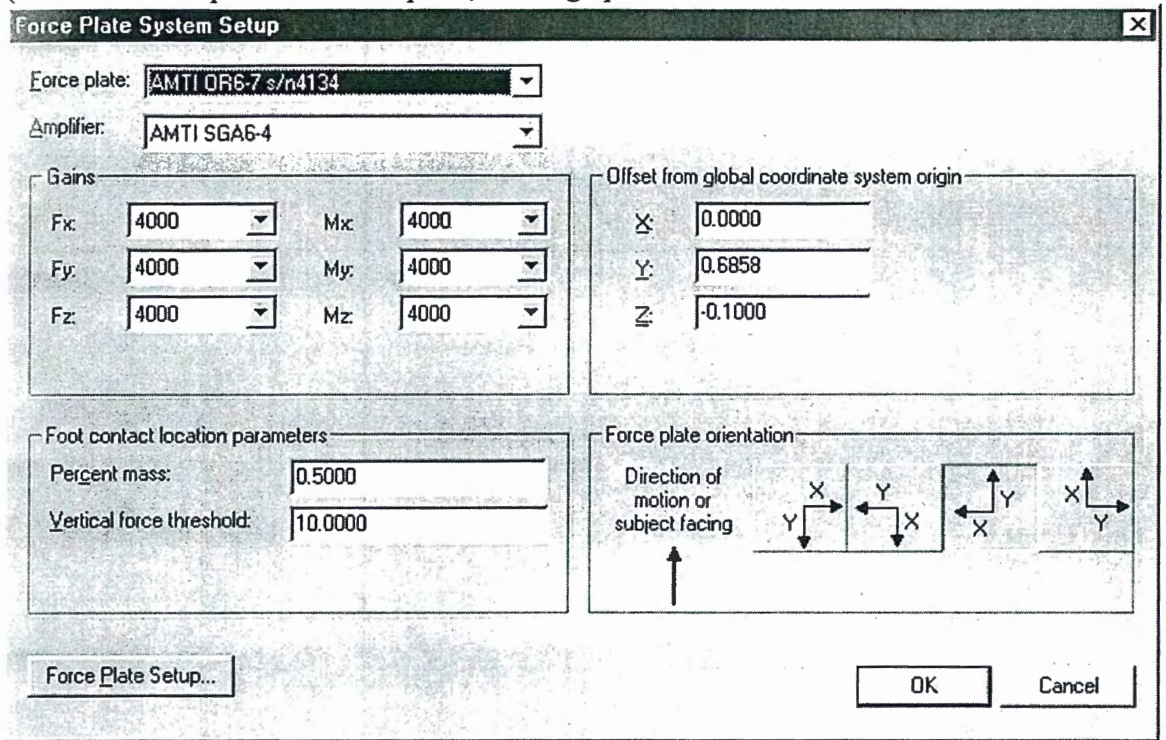

Force Plate Setup
Force plate
Name: AMTI LG6-7 s/n 3891
Model: AMTI LG6-4-1000
Dimensions (m)
X: 0.3048
Y: 0.6100
Z: 0.0700
Offsets (m)
X: 0.0000
Y: 0.0000
Z: -0.0509
Calibration matrix (SI units)
Fx' Fy' Fz' Mx' My' Mz'
Fx 1.5100 0.0000 0.0000 0.0000 0.0000 0.0000
Fy 0.0000 0.6954 0.0000 0.0000 0.0000 0.0000
Fz 0.0000 0.0000 5.9311 0.0000 0.0000 0.0000
Mx 0.0000 0.0000 0.0000 1.3376 0.0000 0.0000
My 0.0000 0.0000 0.0000 0.0000 0.9394 0.0000
Mz 0.0000 0.0000 0.0000 0.0000 0.0000 0.6138
OK
Cancel

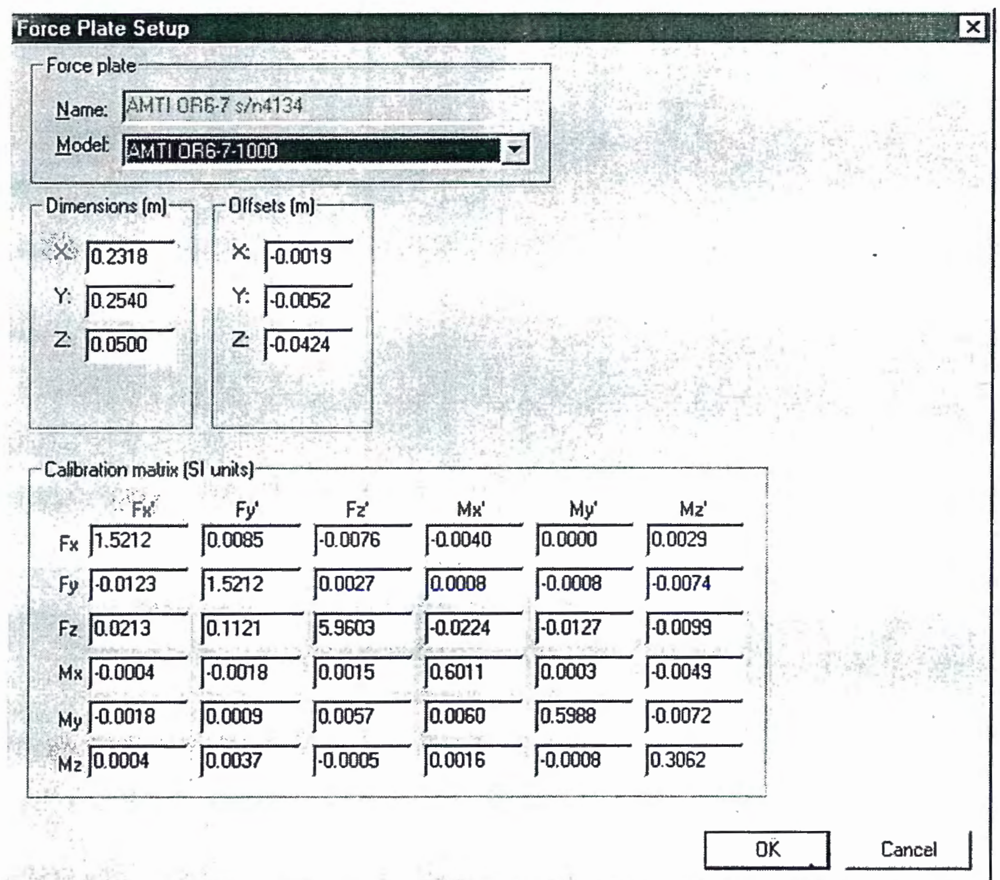
Example of gait analog set up:



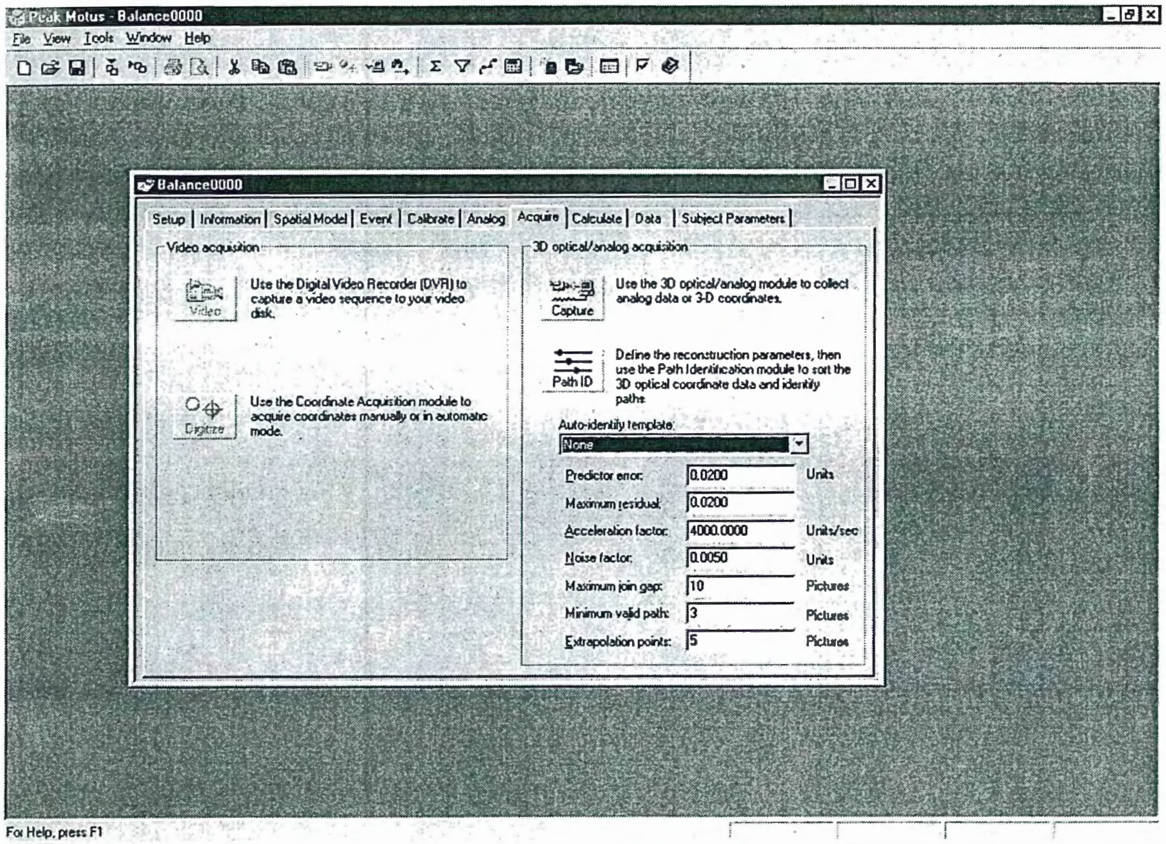


(This is the setup for the small plate, the large plate is the same as seen in the Balance testing)





F. Acquire

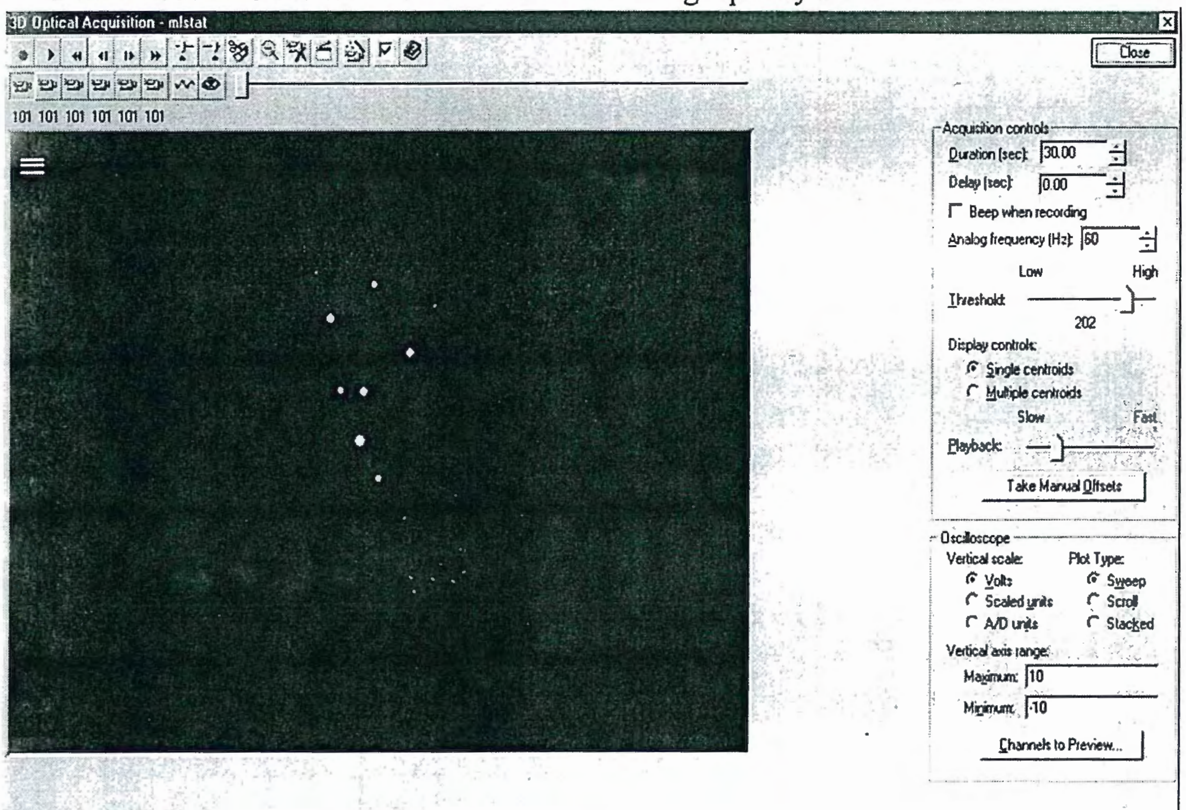


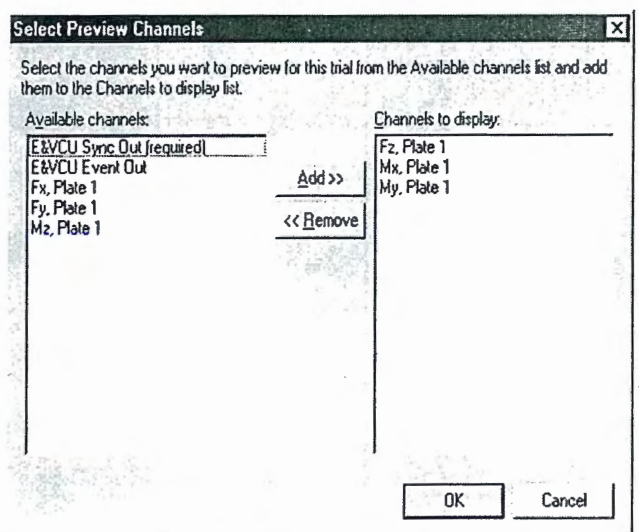
The appropriate template for the posture/task should be listed as auto identify template. Other units are as follows and may be adjusted to optimize path ID:

Prediction error	0.0200
Maximum residual	0.0200
Acceleration factor:	4000.0000
Noise factor	0.0050
Maximum join gap	10 pictures
Minimum valid path	3 pictures
Extrapolation points	5 pictures

1. Capture

Collect for 30 seconds for balance and 10 seconds for gait, no delay, analog frequency of 60 for balance and 600 for gait, single centroids for display controls. Oscilloscope vertical scale is in volts, plot type is sweep, maximum vertical axis surge is 10, minimum is –10. Channels to preview include E&VCU synch out, E&VCU synch event, Fx Plate 1, Fy Plate 1 and Mz Plate 1. Fz, My and Mx should be displayed. Threshold may need to be adjusted according to each camera image quality. Adjust the threshold so that no extra refection appears on the screen in addition to the markers. Check the image quality for all cameras.

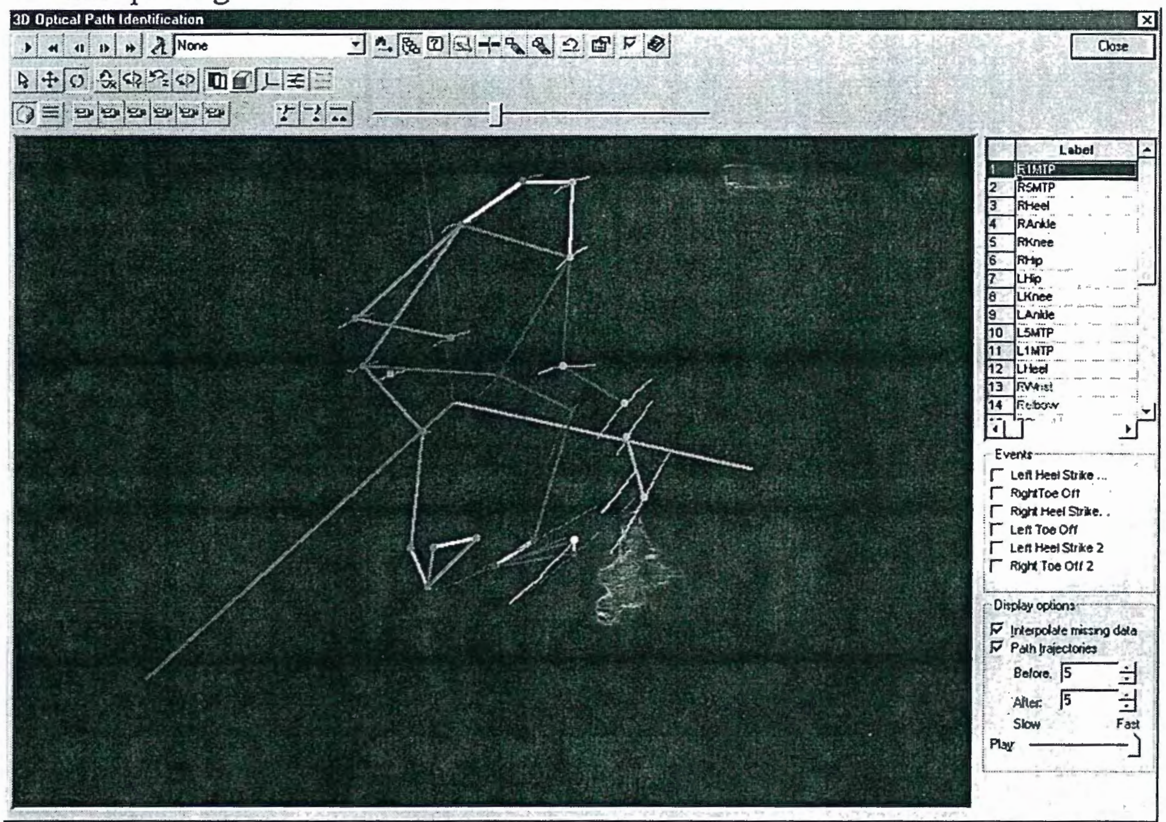




2. Path ID

Display options checked include interpolate missing data and path trajectories (before 5; after 5) The events for the trial should be listed. The investigator will mark each of these events by observing the paths.

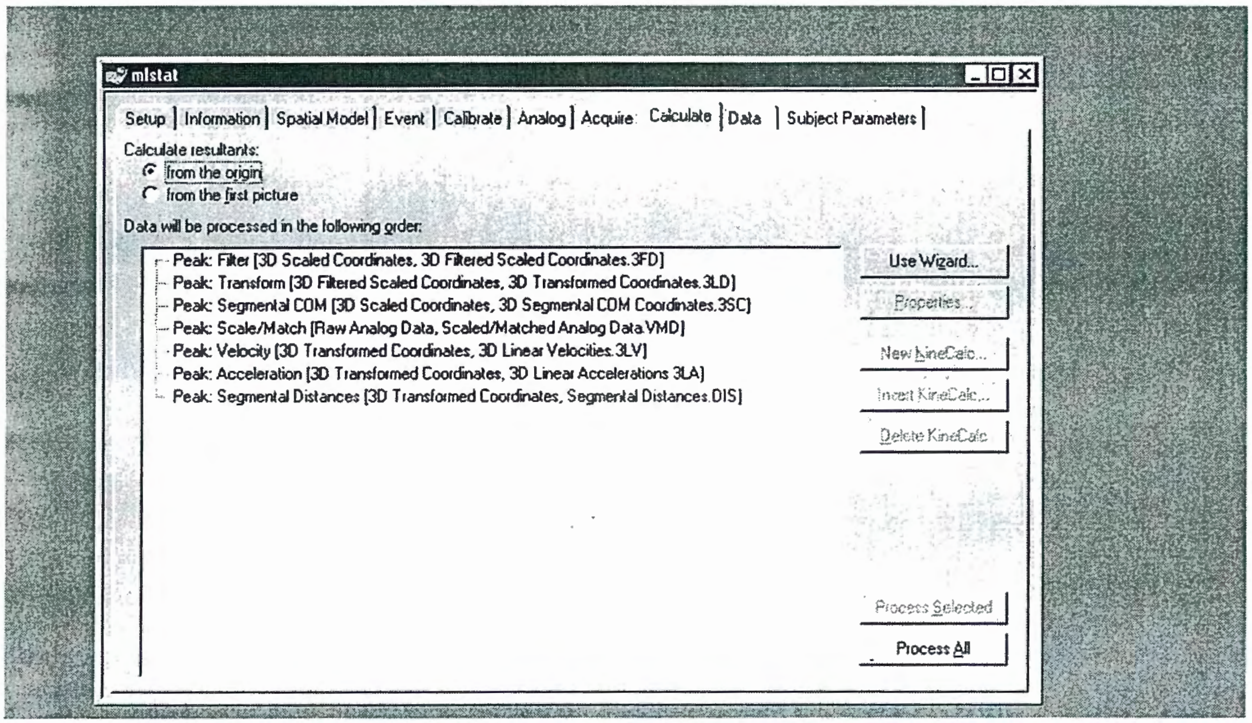
Example of gait trial in Path ID:



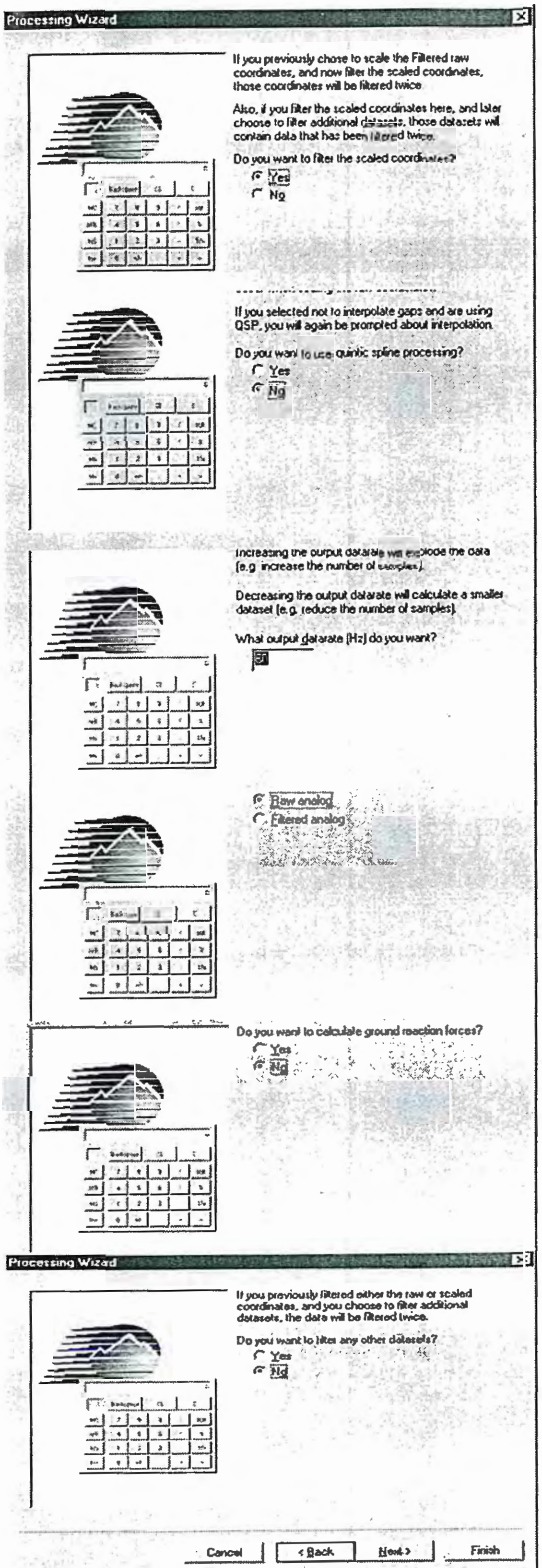
G. Calculate

Resultants should be calculated from the origin. Data to be processed includes

Peak: Filter [3D Scaled Coordinates, 3D Filtered Scaled Coordinated. 3FD]
Peak: Transform [3D Filtered Scaled Coordinates, 3D Transformed Coordinates. 3LD
Peak: Segmental COM [3D Scaled Coordinates, 3D Segmental COM Coordinates. 3SC]
Peak: Scale/Match [Raw Analog Data, Scaled/Matched Analog Data. VMD]
Peak: Velocity [3D Transformed Coordinates, 3D Linear Velocities. 3LV]
Peak: Acceleration [3D Transformed Coordinates, 3D Linear Accelerations. 3LA]
Peak: Segmental Distances [3D Transformed Coordinates, Segmental Distances. DIS]



The Wizard settings should indicate that the scaled coordinates should be filtered, quintic spline processing is not used, output data rate is 60 Hz, raw analog data will be used to scale/match, ground reaction forces are not calculated, and no other data sets are filtered. Note that you do not need to go through the Wizard for the setting since the setting has been saved in the template. Therefore, just click on "Process All" to process data. The following setting is for your reference.


Processing Wizard
If you previously chose to scale the Filtered raw coordinates, and now filter the scaled coordinates, those coordinates will be filtered twice.
Also, if you filter the scaled coordinates here, and later choose to filter additional datasets, those datasets will contain data that has been filtered twice.
Do you want to filter the scaled coordinates?
Yes
No
If you selected not to interpolate gaps and are using QSP, you will again be prompted about interpolation.
Do you want to use quintic spline processing?
Yes
No
Increasing the output datarate will explode the data (e.g. increase the number of samples).
Decreasing the output datarate will calculate a smaller dataset (e.g. reduce the number of samples).
What output datarate (Hz) do you want?
Raw analog
Filtered analog
Do you want to calculate ground reaction forces?
Yes
No
Processing Wizard
If you previously filtered either the raw or scaled coordinates, and you choose to filter additional datasets, the data will be filtered twice.
Do you want to filter any other datasets?
Yes
No
Cancel
< Back
Next >
Finish

APPENDIX I

BORG scale

THE RATING OF PERCEIVED EXERTION SCALE (BORG, 1980)

20

19 VERY, VERY HARD

18

17 VERY HARD

16

15

14

13 SOMEWHAT HARD

12

11 FAIRLY LIGHT

10

9

8

7 VERY, VERY LIGHT

6

APPENDIX J

PSOS scale

RATING OF PERCEIVED SENSE OF SLIP DURING A POSTURAL STABILITY/SWAY 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/Sway Test (stationary, reach, sudden loading) you will be asked to estimate your sense of how much your body slipped on the plate while doing the sway/postural stability tests. When asked by the facilitator to rate how much your body slipped during that test, indicate the number that corresponds best with what you felt. For instance, if you felt your body slip 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 yourself slip (i.e., loose traction)?

   a little **some** **a lot**

   -0- **-0.5-** **-1-** **-1.5-** **-2-**

2. Did you feel at any time you would slip and fall?

   none **a little** **a lot**

   -0- **-0.5-** **-1-** **-1.5-** **-2-**

3. Did you have any difficulty in maintaining balance while performing the task?

   none **a little** **a lot**

   -0- **-0.5-** **-1-** **-1.5-** **-2-**

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

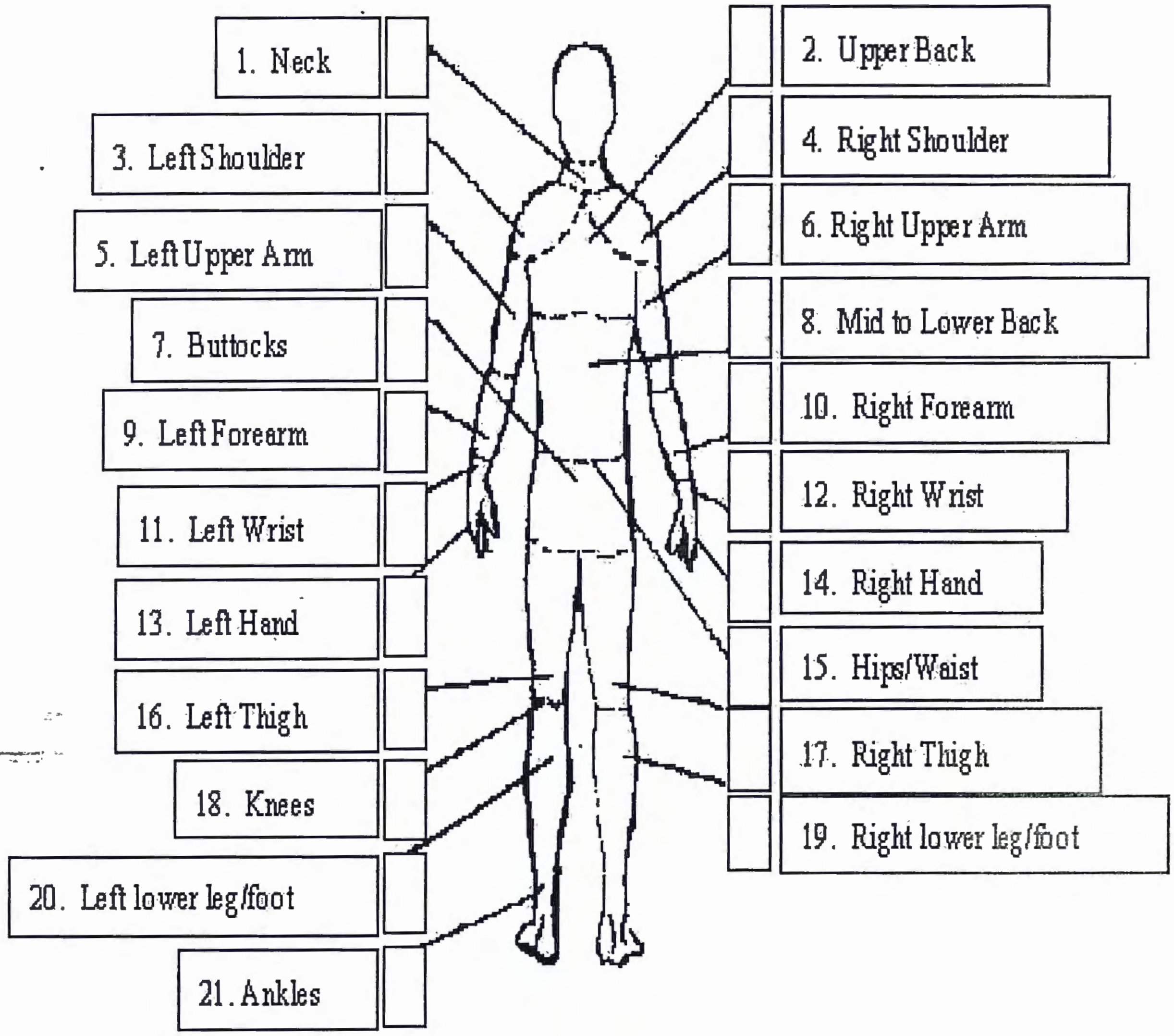
   very easy **easy** **moderate** **somewhat hard** **hard**

   -0- **-0.5-** **-1-** **-1.5-** **-2-**

APPENDIX K

Modified Bishop-Corlett scale

MODIFIED BISHOP-CORLETT SCALE



Scale:

(0) Comfortable

(1) Uncomfortable

(2) Very Uncomfortable

(3) Extremely Uncomfortable

APPENDIX L

Consent Form

UNIVERSITY OF CINCINNATI

Consent to Participate in a Research Study

Title of Study:
Postural stability effects in low seam mining tasks

Investigator Information:

Amit Bhattacharya, Ph.D. (513) 558 -0503
Principal Investigator Telephone number

Angshuman Bagchee, Ph. D.

Paul Succop, Ph.D.
Co-investigators

Introduction
Before agreeing to participate in this study, it is important that the following explanation of the proposed procedures to be read and understood. It describes the purpose, procedures, benefits, risks, 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.

I ______________________________ have been asked to participate in the research study under the direction of Dr. Amit Bhattacharya. Other professional persons who work with him as study staff may assist or act for him.

I will be one of approximately thirty subjects to participate in this trial.

Purpose
The purpose of this research study is to investigate the effect of handling (lifting/carrying) hand-held load in a stooped and upright posture.

Duration
I will participate for a maximum of ten sessions, one on each separate day, each session lasting about 3 to 4 hours. Additionally, I will be participating in a preliminary session to evaluate my physical condition and medical examination to determine my ability to perform the study.

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

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

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 evaluation results will be used to determine my ability to perform the tests.

C. I will be given ten different dates to participate in the test sessions. I understand that I will be participating in approximately four-hour sessions on each day.

D. I will abstain from alcohol for at least forty-eight (48) hours prior to testing. I will also abstain from tobacco and caffeine for at least twelve (12) hours prior to testing.

E. The tests will be performed at Room 313, Kettering, located in University of Cincinnati Medical School, Cincinnati, Ohio 45267.

F. On the day of the test, I will wear specialized clothing (as required by investigator) to perform the tests satisfactorily. Reflective markers will be placed externally on my arms, legs, and body for videotaping my movement.

G. A test will consist of two types of tasks: 1) Static tests (such as standing, reaching, lifting a weight of 5 lbs from knee height to about my chest height and lifting from floor to chest height; these tasks will be carried out once in stooping and once in kneeling positions). 2) Dynamic tasks (such as walking upright with and without a 5 lbs weight in hand, walking in stoop posture with and without 5 lbs weight in hand). These tasks will be carried out in various combinations of the following environmental conditions. <u>Condition 1:</u> good lighting, poor lighting and glare type of lighting, <u>Condition 2:</u> firm, slippery and uneven standing/walking surfaces, <u>Condition 3:</u> low ceiling and unrestricted ceiling. During the dynamic task test, I will walk normally from one end of the walkway to the other and back. I will be asked to wear new shoes (Redwing brand) provided by the investigator. During the walking, I will be stepping on a force platform in the middle of the walkway, flush with the floor, which will record the forces and moments generated when I strike the ground with my foot. I will be tested with all possible combinations of these conditions. Each individual task of walking will last approximately 30 seconds. Four cameras will be used for recording the movement of my body and the markers on my body.

H. After each task, I will be asked to rate my perceived sense of slip during the task by answering a set of four questions.

I. On another day, the above procedures will be repeated for a different combinations of Conditions 1,2 and 3 and Static and Dynamic tasks as explained in item #G.

Exclusion
I should not participate in this study if any of the following apply to me:

A history of ocular pathology, dizziness, tremor, alcoholism, vestibular disorders, neurological disorders, cardiopulmonary disorders, diabetes, chronic or acute lower back pain, knee pain. Also, if I have fallen in the past year, I will not be selected for this study.

Risks/Discomforts
I understand that there exists the possibility of certain changes in my body during the test. They include irregular breathing and heartbeat. 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 be available to deal with any unusual situations, which may arise. I understand that during the gait tests only I will be wearing a safety harness hooked to an overhead rail system to prevent fall if a slip occurs. Impact resistance pads will be placed near the experimental setup and

observers will be near me at all times during the test to secure against the 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.

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 the resident physician. I agree to inform the investigator's immediately if: 1) I have any reason to suspect pregnancy; 2) I find that circumstances have changed and that there is now a risk of becoming pregnant; or 3) I have stopped using the approved form of birth control.

Benefits
I have been told that I will receive no direct benefit from my participation in this study, but my participation may help better design criteria for manual material handling tasks on various kinds of surfaces, ceiling heights and environmental lighting conditions. This study will help identify hazards and help minimize the same by employing safe work practices, based on the finding of this study.

New Findings
I have been told that I will receive any new information during the course of the study concerning significant findings that may affect my willingness to continue my participation.

Confidentiality
Every effort will be made to maintain confidentiality of my study records. Agents of the United States Food and Drug Administration and the University of Cincinnati will be allowed to inspect my medical and research records related to this study. The data from the study may be published: however, I will not be identified by name. My identity will remain confidential unless disclosure is required by law.

Financial Costs to Subject
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, procedures or other costs incurred solely for purposes of research will not be my financial responsibility. If I have questions about my medical bill relative to research participation, I may contact Dr. Amit Bhattacharya (513-558-0503).

Compensation in Case of Injury
The University of Cincinnati Medical Center follows a policy of making all decisions concerning compensation and medical treatment for injuries 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 the IRB Chairperson at 513-558-5259 or Dr. Amit Bhattacharya at 513-558-0503. I understand that by signing this informed consent statement I am not waiving my right to seek any legal options to which I am entitled.

Payments to Participants
I have been told that I will receive $50 per visit for my participation on testing days and $25 for medical evaluation visit.

Right to Refuse or Withdraw
I understand that my participation is voluntary and I may refuse to participate, or may discontinue my participation at any time, without penalty or loss of benefits to which I am otherwise entitled. I also understand that the investigator has the right to withdraw me from the study at any time. I understand that my withdrawal from the study may for reasons related solely to me (e.g. not following study-related directions from the investigator; a serious adverse reaction) or because the entire study has been terminated.

Offer to Answer Questions
This study has been explained to my satisfaction by ______________________
and my questions were answered. If I have any other questions about this study, I may call Dr. Amit Bhattacharya at 513-558-0503. If I have any questions about my rights as a research subject, I may call the IRB Chairperson at 513-558-5259. If a research related injury occurs, I will call the IRB Chairperson at 513-558-5259.

Participation in Another Study
Are you currently participating in another study? If yes, please provide the following information:

☐ YES. If yes, please provide the Principal Investigator's name and title of study.
Principal Investigator's name: ______________________
Title of study: ______________________

☐ NO.

I have read the information provided above. I voluntarily agree to participate in this study. After it is signed, I will receive a copy of this consent form.

Subject Signature Date

Legal Representative Parent Date

Signature of Investigator Date

Witness Signature Date

☐ Check box if verbal assent is obtained by investigator.

APPENDIX M

Session Interview

MINERS STUDY
Modified DOV

Name:________________ Subject ID: ________Date:_____________ Session #:_______

1. Have you worked in the last twelve hours? .... 1. Yes 0. No _______
   a. If **YES**, how many hours? .... #hours _______

2. Have you changed shifts in the last week? .... 1. Yes 0. No _______
   a. What were the hours of your previous shift? ....______ to ______
   b. What are the hours of your current shift? ....______ to ______

3. Using the rating scale shown below; please rate the **OVERALL** physical effort level you experienced for the last twelve hours? Please <u>circle</u> the most appropriate number on the following scale.

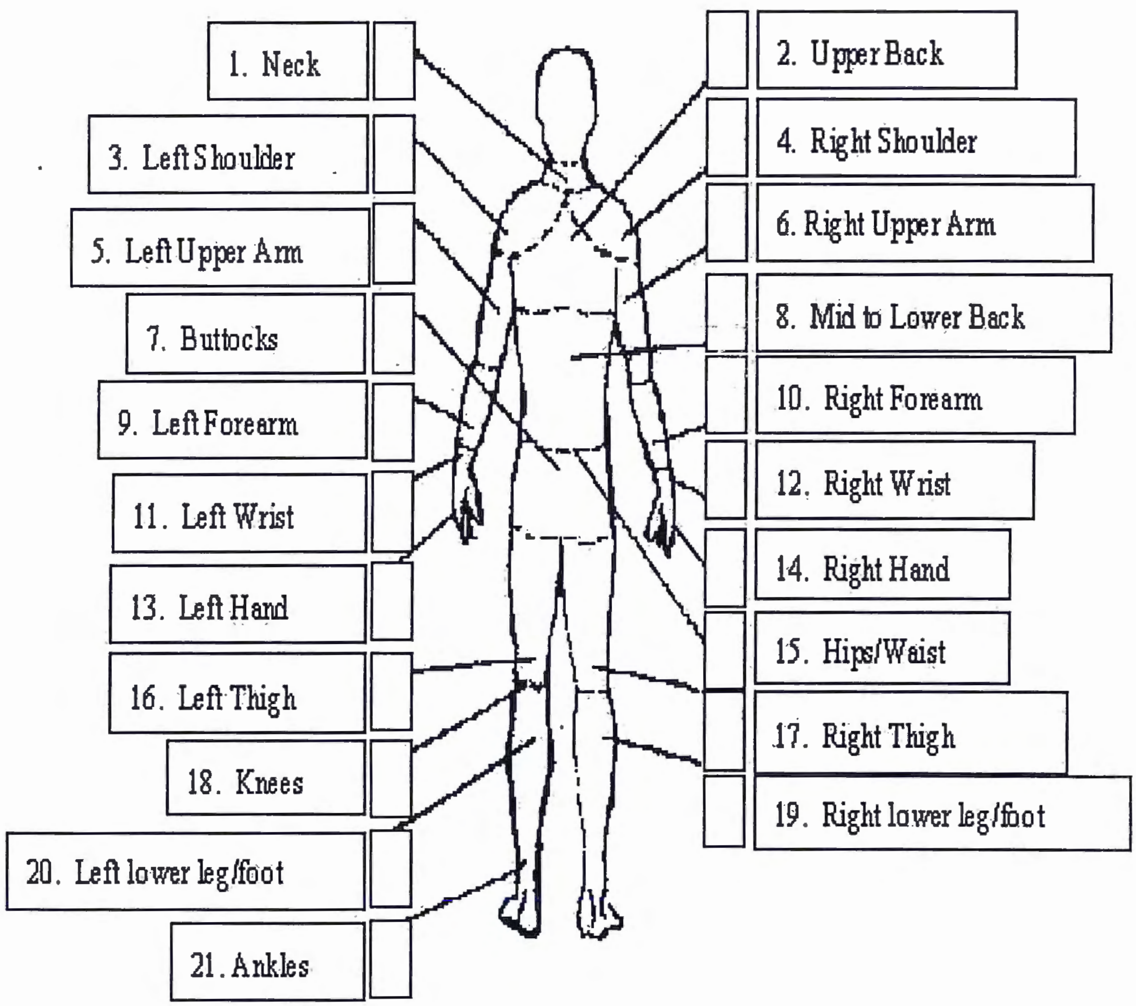
20
19 - Very, very hard
18
17 - Very hard
16
15 - Hard
14
13 - Somewhat hard
12
11 - Fairly light
10
9 - Very light
8
7 - Very, very light
6

PRE TESTING DISCOMFORT RATINGS

4. Have you had any pain or discomfort in the last twelve hours? .... 1. Yes 0. No ________

If YES, mark in the appropriate box using the following scale:

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



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

____

6. Asleep:________Woke:_______ #hrs slept: ____________

7. Did you sleep all night?: 1=yes 0=no 3=unknown ____________

8. Time ate last: #hrs since last meal ____________

9. Caffeine last 12 hours: 1=yes 0=no 3=unknown .... ____________

a. Type: 1=coffee 2=tea 3=soda 4=cocoa 5=combo 6=none.........____________

b. amount: enter # ounces .... ____________

10. # cigarettes smoked in last 12 hours:.. ____________

a. time last cigarette:.. ____________

11. Sick in the last week:.. ____________

12. Any recent surgery including dental:................................ ____________

13. Ear infection since last visit: .... ____________

hx

14. Currently taking any meds (last 24 hrs): .... ____________

hx

15. Injuries to head neck or back since last visit: .... ____________

hx

16. Have you fallen/slipped on the job since last visit: .... ____________

hx

17. In the last 24 hours, strenuous activity: .... ____________

hx

18. Stressful events at home or job in last 24 hrs:............................____________

hx

19. Alcohol consumption in the last 48 hours: ....____________

a. type: 1=beer 2=liquor 3=wine 4=none..............................____________

b. amount consumed: enter # ounces .... ____________

20. Recreational drugs ingested in the last 24 hours: .... ____________

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

b. freq./amount in last 24 hours .... ____________

21. Are you pregnant? (LMP)____________________ 1= yes 0 = no (no includes PM & NA)

PM - post menopause

NA - not applicable, male

22. Oral Temperature: ______° Blood Pressure: _____/_____ Weight(kg)________________

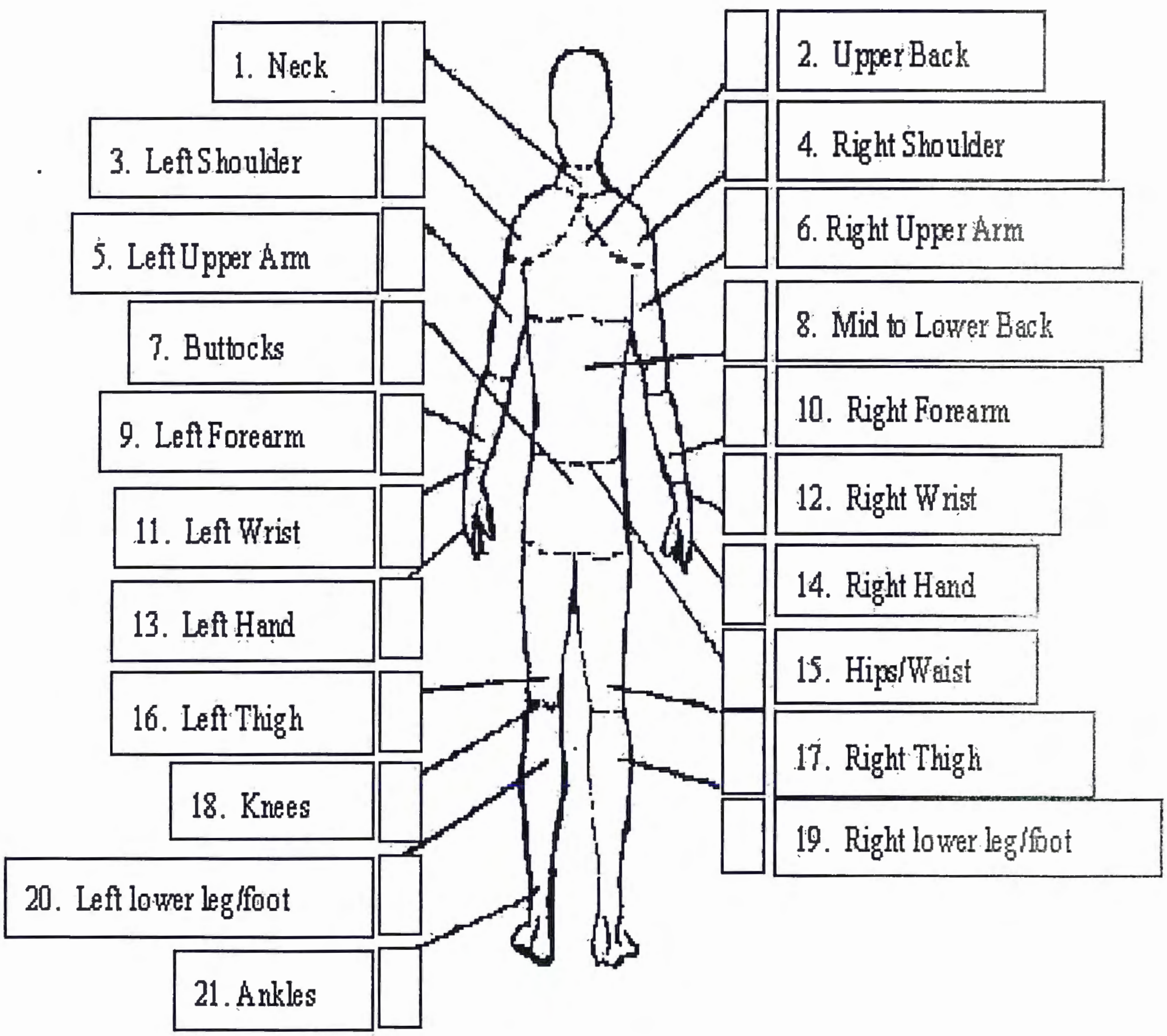
POST TESTING DISCOMFORT RATING

23. Since the beginning of the testing session have your experienced discomfort in any of the body parts listed?

1. Yes   0. No   ___________

If **YES**, mark in the appropriate box using the following scale:

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



APPENDIX N

Examples of raw kinetic and kinematic data

D.5. Examples of raw kinetic and kinematic data during balance and gait trials

Figures 1 - 10 show examples (from one subject) of the corresponding changes in forces (Fx, Fy, and Fz) for balance (1 - 8) and gait (9 - 10) trials using the force platform [one plate (small plate) for the balance trials and two plates (one small and one large plates) for the gait trials] throughout the trial period. Figures 11 – 20 show the corresponding changes in moments (Mx, My and Mz) for balance (11 – 18) and gait (19 – 20). In addition, figures 21 - 30 show whole body CG movements (x, y and z) during balance (21 – 28) and gait (29 – 30) tasks. The numbered vertical lines mark the events for each trial. Events for each task are described below.

D.5.a. Balance Tasks

All balance tasks were performed for 30 seconds. Tasks were repeated under different environmental conditions following the original study protocol (see section C.2). **Best conditions** imply that the subject performed the task on firm dry surface, kneeling on 2 knees, and with poor lighting condition. **Worst conditions** imply performing the same task on firm slippery surface, kneeling on 1 knee, and with glare lighting condition.

Stationary

For the stationary task, the subject kneels below the restricted ceiling, relaxed with their wrists resting on each respective thigh for 30 seconds. (**No events** were marked for this task)

Lifting a bucket of bits

For this task, a bucket was lifted from the ground, on the left side of the subject up to a 34" shelf on the right of the subject and returned back to the ground. A voice command to begin the lift was given 8 seconds into the 30 second trial. The subject began the trial kneeling in a relaxed position as in a stationary trial. On the voice command, the subject reached for the bucket and began the lift cycle. **Four events** were marked during this task; 1-beginning of motion, 2-contact with bucket, 3-release of bucket, and 4-end of motion.

Cable lifting

For this task, the subject lifted a section of "cable" from the floor level in front of the force platform, up to the false ceiling and finally replaced the cable to the starting position. The subject began the lift on a voice command given after 8 seconds of inception of the test and relaxed for the remainder of the 30-second test after the lift. **Four events** were marked during this task; 1-beginning of motion, 2-contact with cable, 3-release of cable, and 4-end of motion.

Scaling

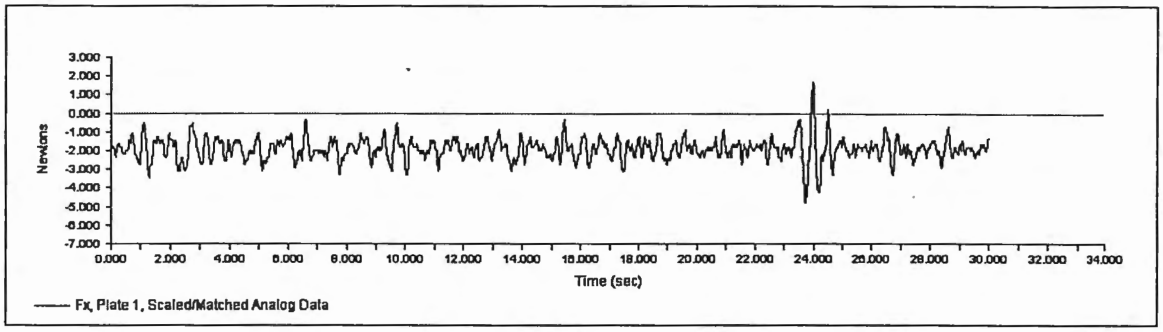
For this task, the subject began with a slabber bar in his/her hands and on a voice command raised the bar and insert it into position A marked on the scaling structure. The subject "pried" there once and moved the bar to position B and "pried" once there. After the second "pry", the subject returned the bar to the starting position for the remainder of the 30-second test. **Two events** were marked during this task; 1-beginning of motion and 2-end of motion.

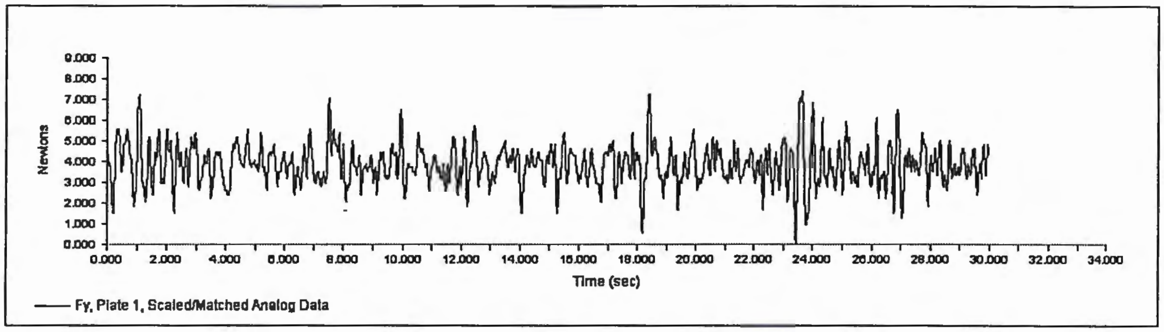
D.5.b. Gait Tasks

For gait trials, the subjects were asked to squat below a certain height marked by ropes (44 inches simulating working in a low seam mine) before beginning to walk and to remain low throughout the trial. Subjects were asked to walk in one direction, and step on two force plates to achieve one heel strike per plate during the gait cycles. The gait for the miners was done with a hammer in their right hand. They used it as a cane and it added another "foot" to their base of support. This hammer struck the ground approximately with the left foot, and the gait setup was made in such a way that the hammer did not strike any of the force plates during the trial. (see Section C.4.a. for more details).

Best conditions imply that the subject performed the task on firm dry surface, with poor lighting condition, wearing leather boots, and carrying no weight. **Worst conditions** imply performing the same task on firm slippery surface, with glare lighting condition, wearing rubber boots, and carrying a 14.5 kg (20 lbs) bag of rice of their back, supported by their left arm (the bag of rice was used to simulate a manual material handling task common in mines).

Nine events were marked during gait trials; 1-left heel strike on the large plate, 2-hammer strike, 3-right toe off, 4-hammer off, 5-right heel strike on small plate, 6-left toe off, 7-left heel strike on ground, 8-hammer second strike, and 9-right toe off.





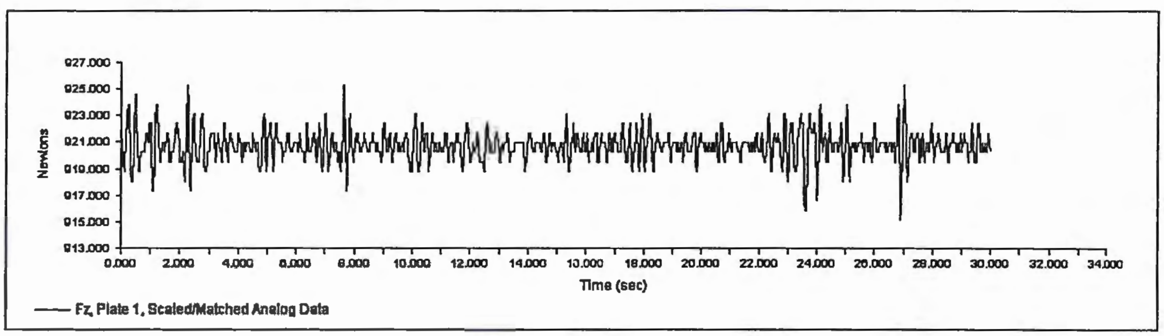


Figure1. Stationary trial under best conditions (firm dry surface, 2-knees position, and poor light) showing the changes in Fx, Fy, and Fz collected on the force platform.

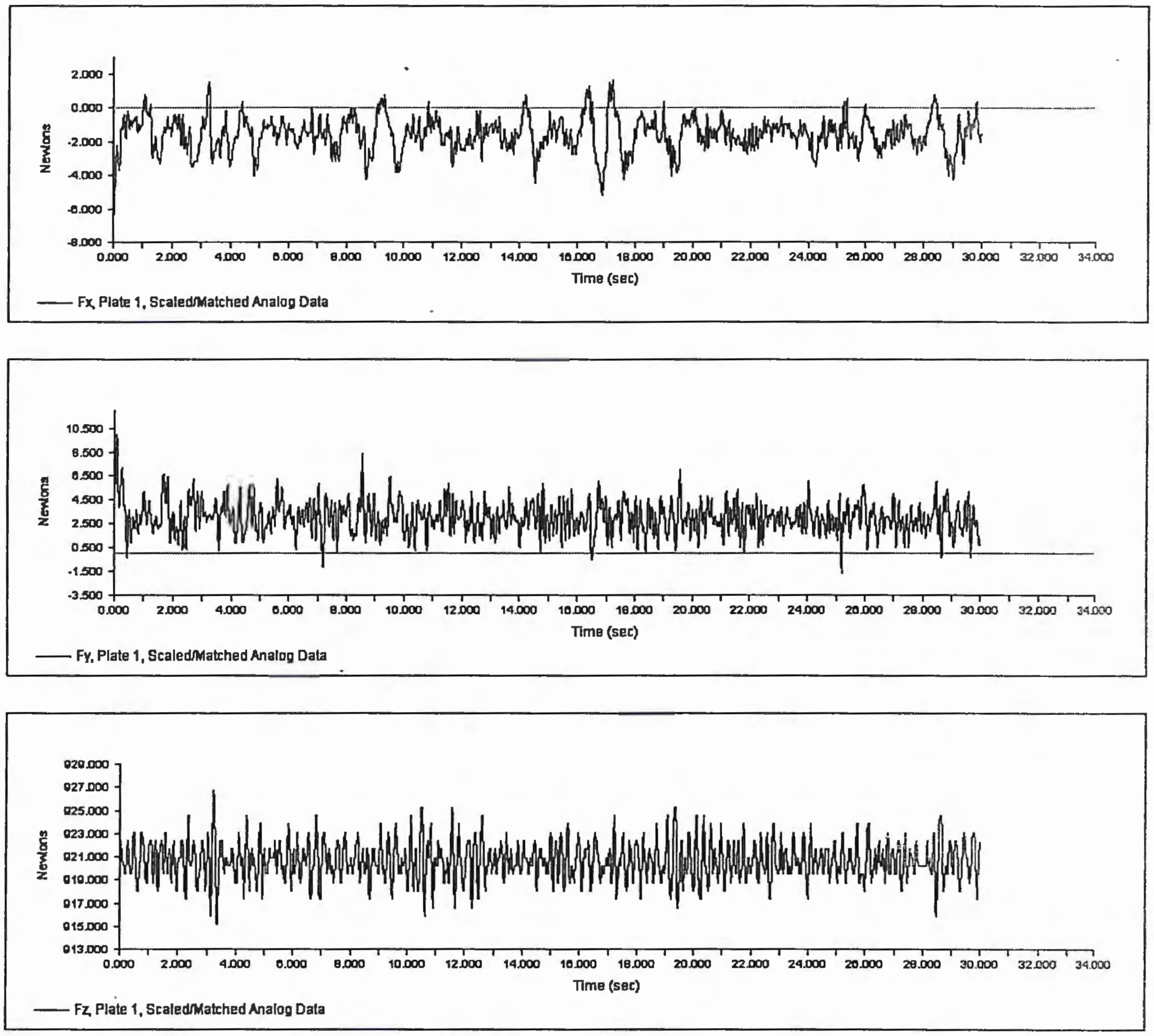


Figure2. Stationary trial under worst conditions (firm slippery surface, 1-knee position, and glare light) showing the changes in Fx, Fy, and Fz collected on the force platform.

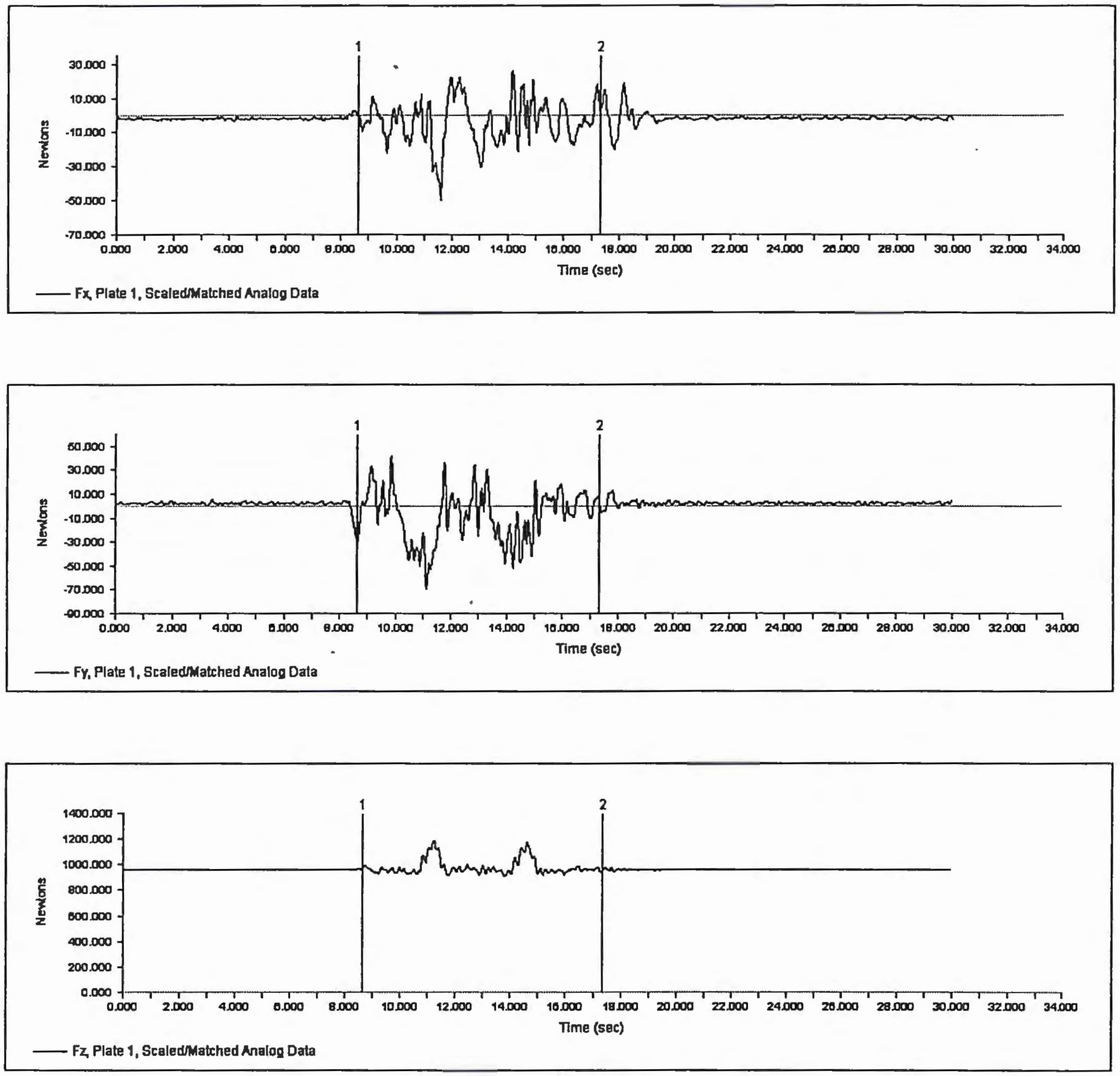


Figure3. Scaling trial under best conditions (firm dry surface, 2-knees position, and poor light) showing the changes in Fx, Fy, and Fz collected on the force platform.

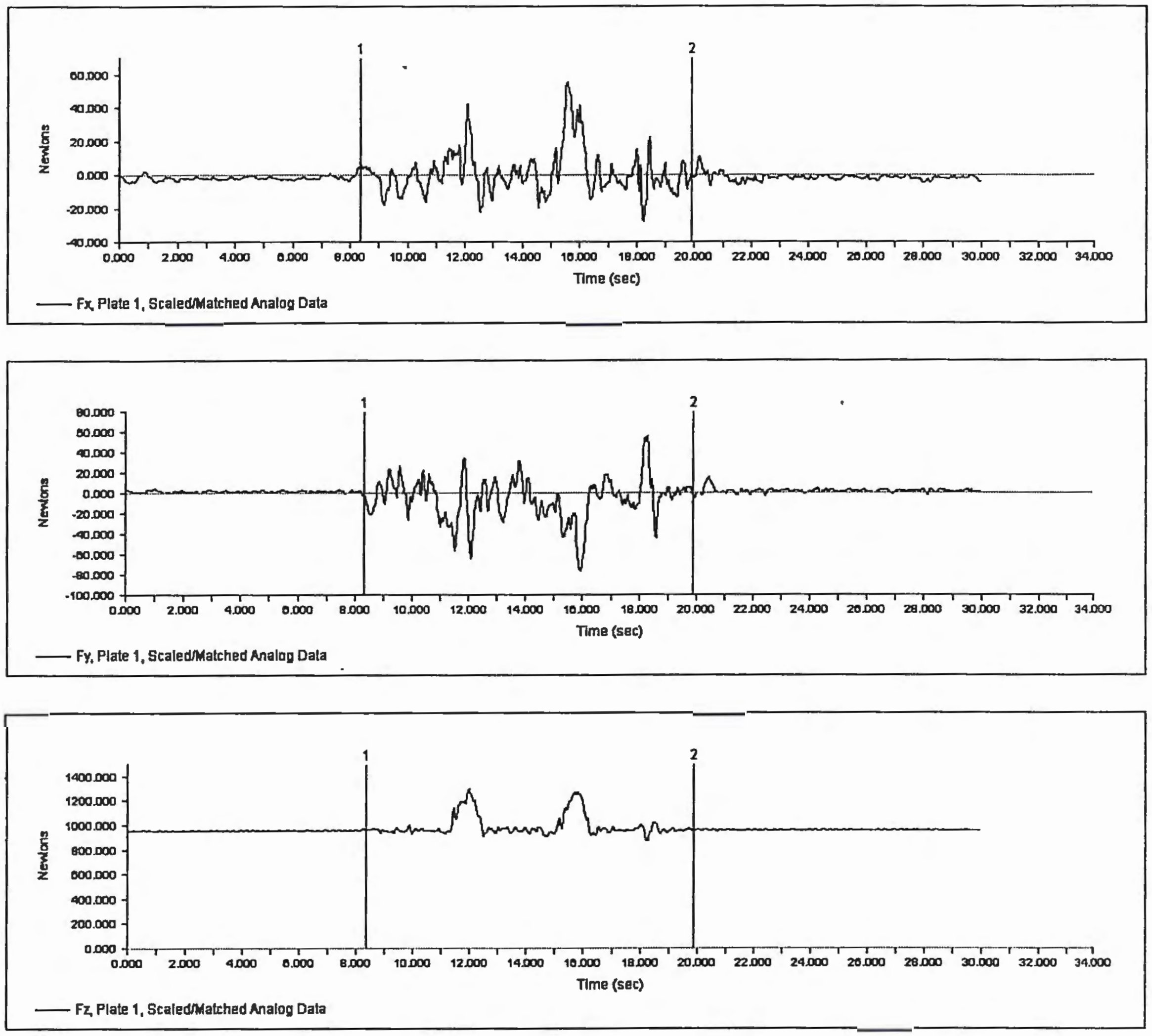


Figure 4. Scaling trial under worst conditions (firm slippery surface, 1-knee position, and glare light) showing the changes in Fx, Fy, and Fz collected on the force platform.

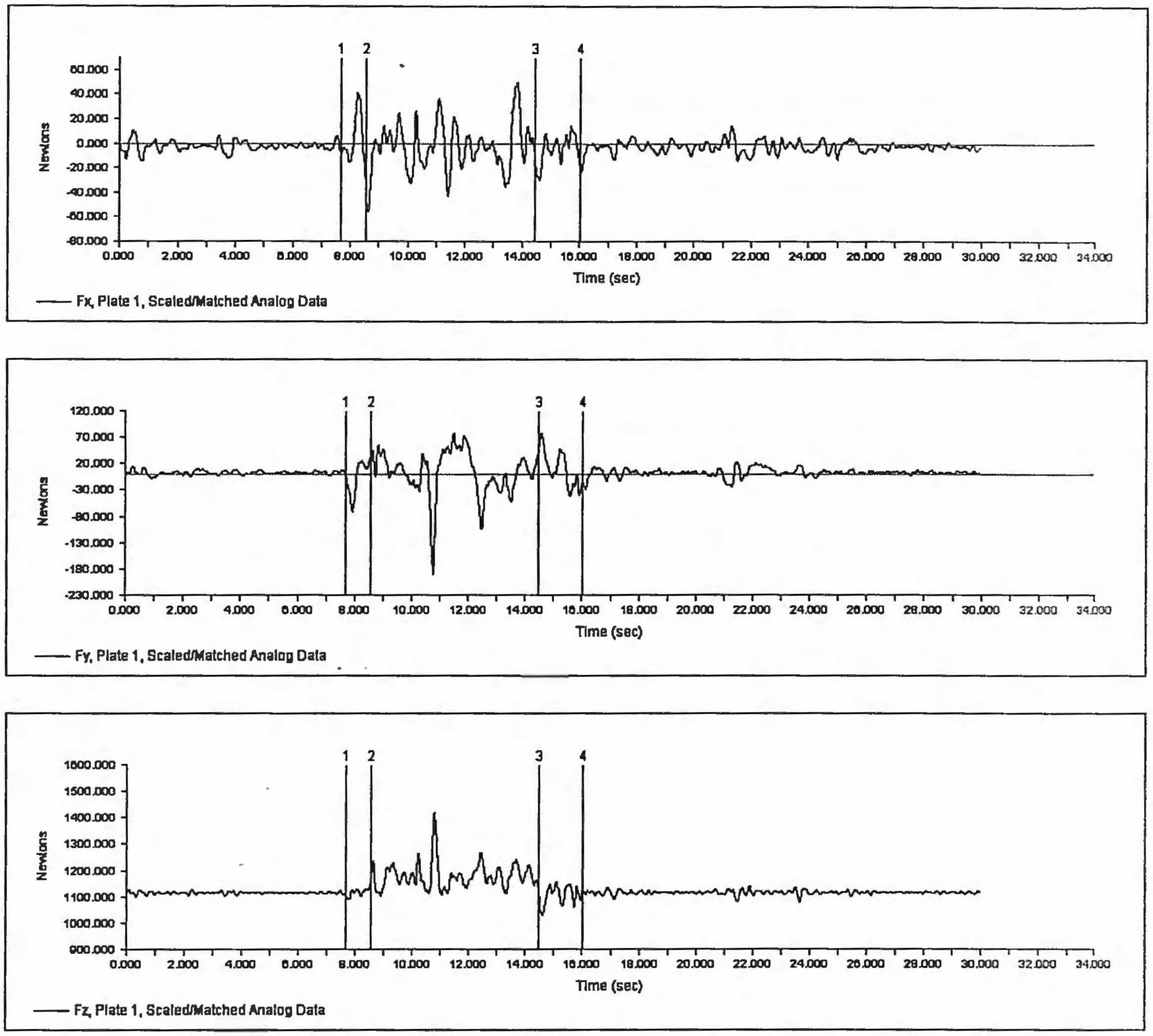


Figure5. Cable trial under best conditions (firm dry surface, 2-knees position, and poor light) showing the changes in Fx, Fy, and Fz collected on the force platform.

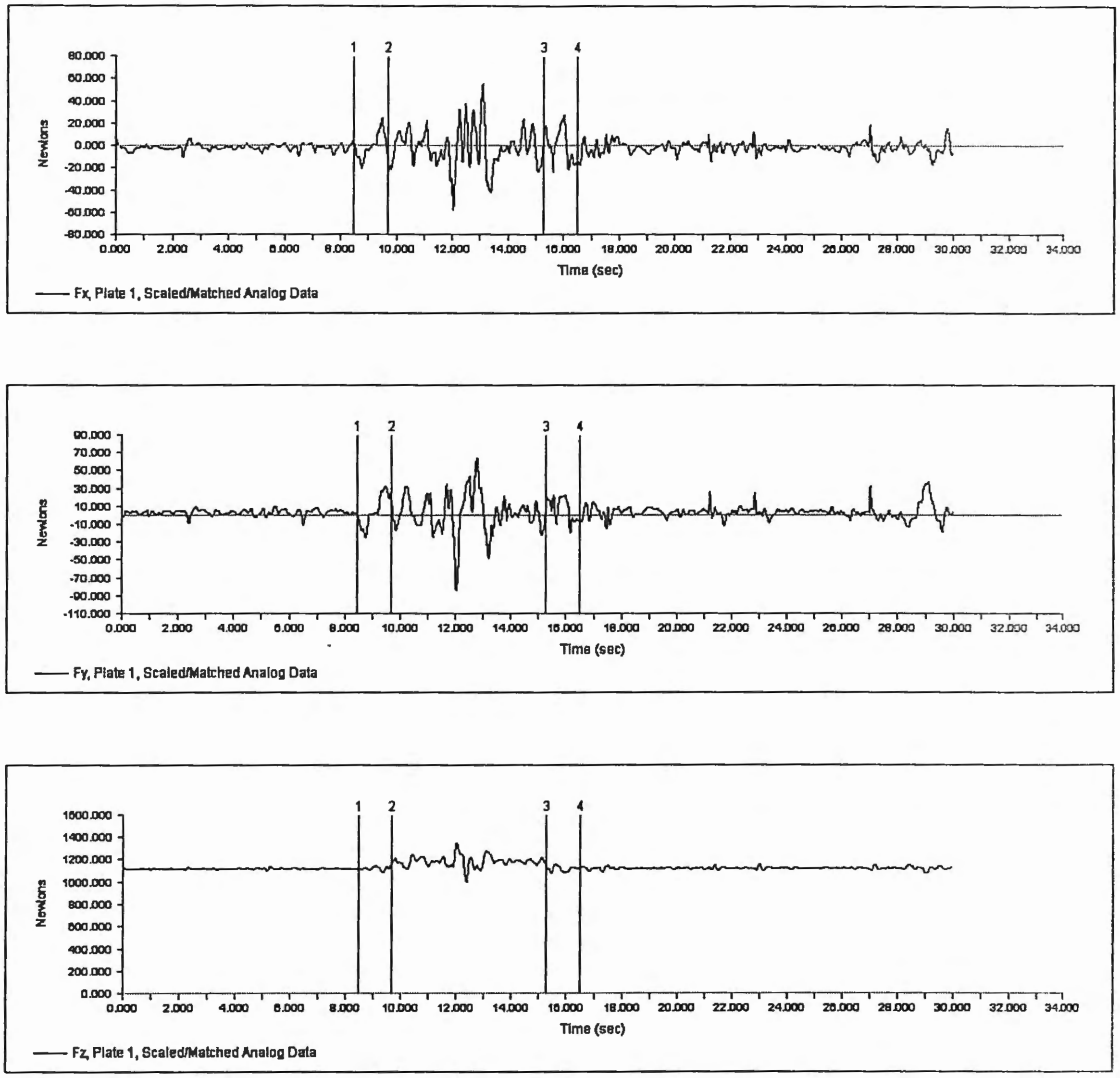


Figure 6. Cable trial under worst conditions (firm slippery surface, 1-knee position, and glare light) showing the changes in Fx, Fy, and Fz collected on the force platform.

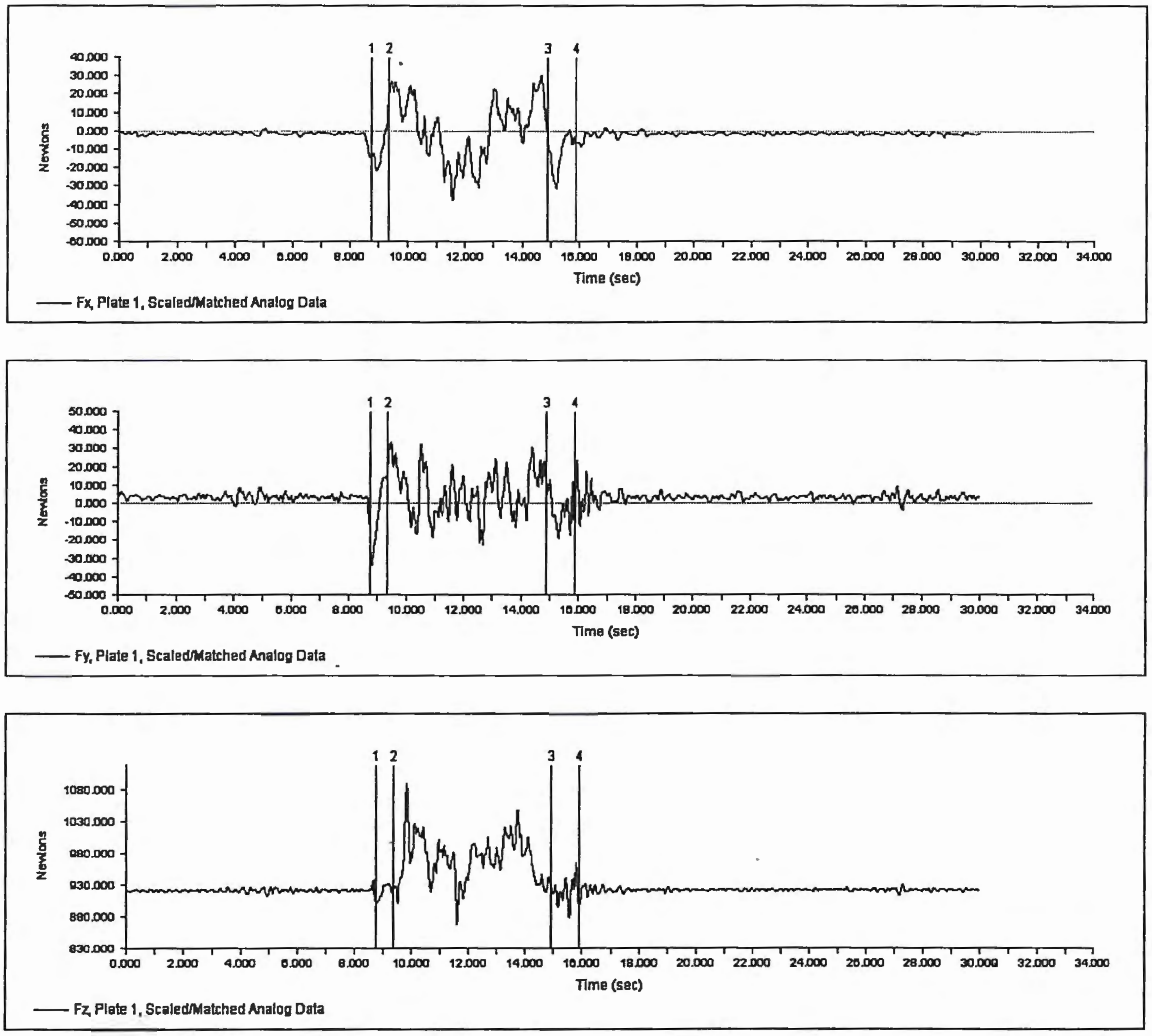


Figure7. Bits trial under best conditions (firm dry surface, 2-knees position, and poor light) showing the changes in Fx, Fy, and Fz collected on the force platform.

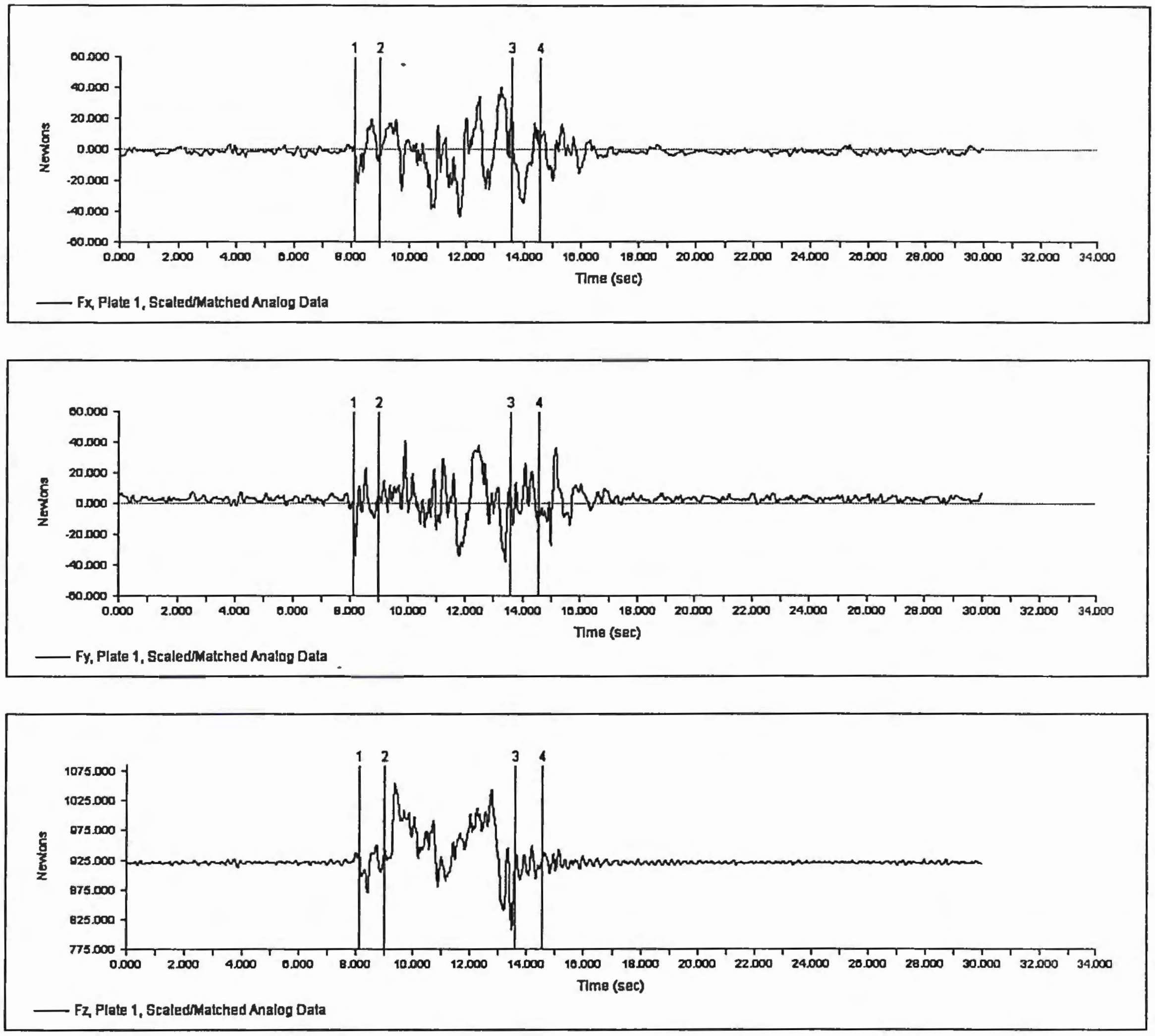


Figure 8. Bits trial under worst conditions (firm slippery surface, 1-knee position, and glare light) showing the changes in Fx, Fy, and Fz collected on the force platform.

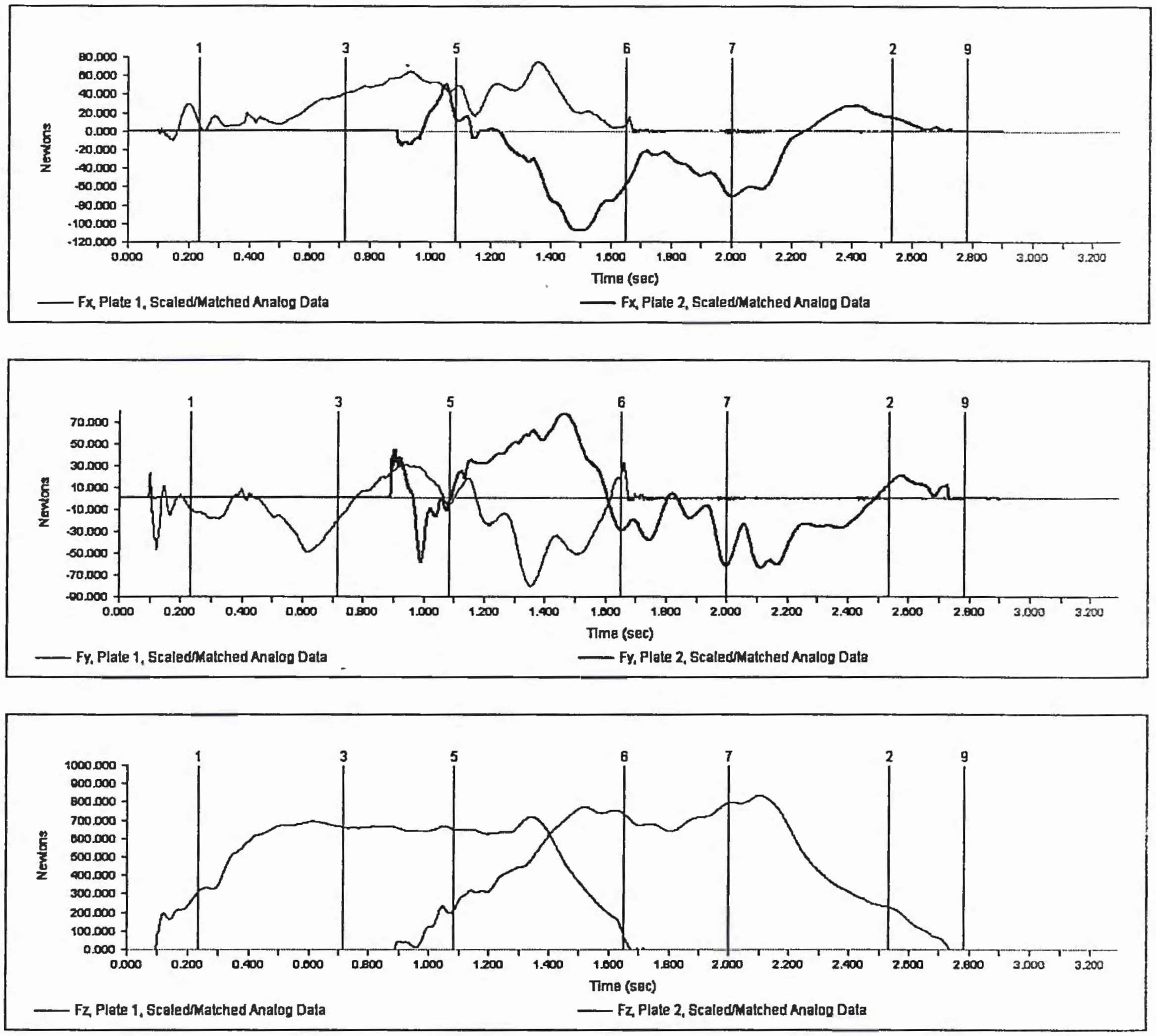


Figure 9. Gait trial under best conditions (firm dry surface, no weight, leather boots, and poor light) showing the changes in Fx, Fy, and Fz collected on the force platform.

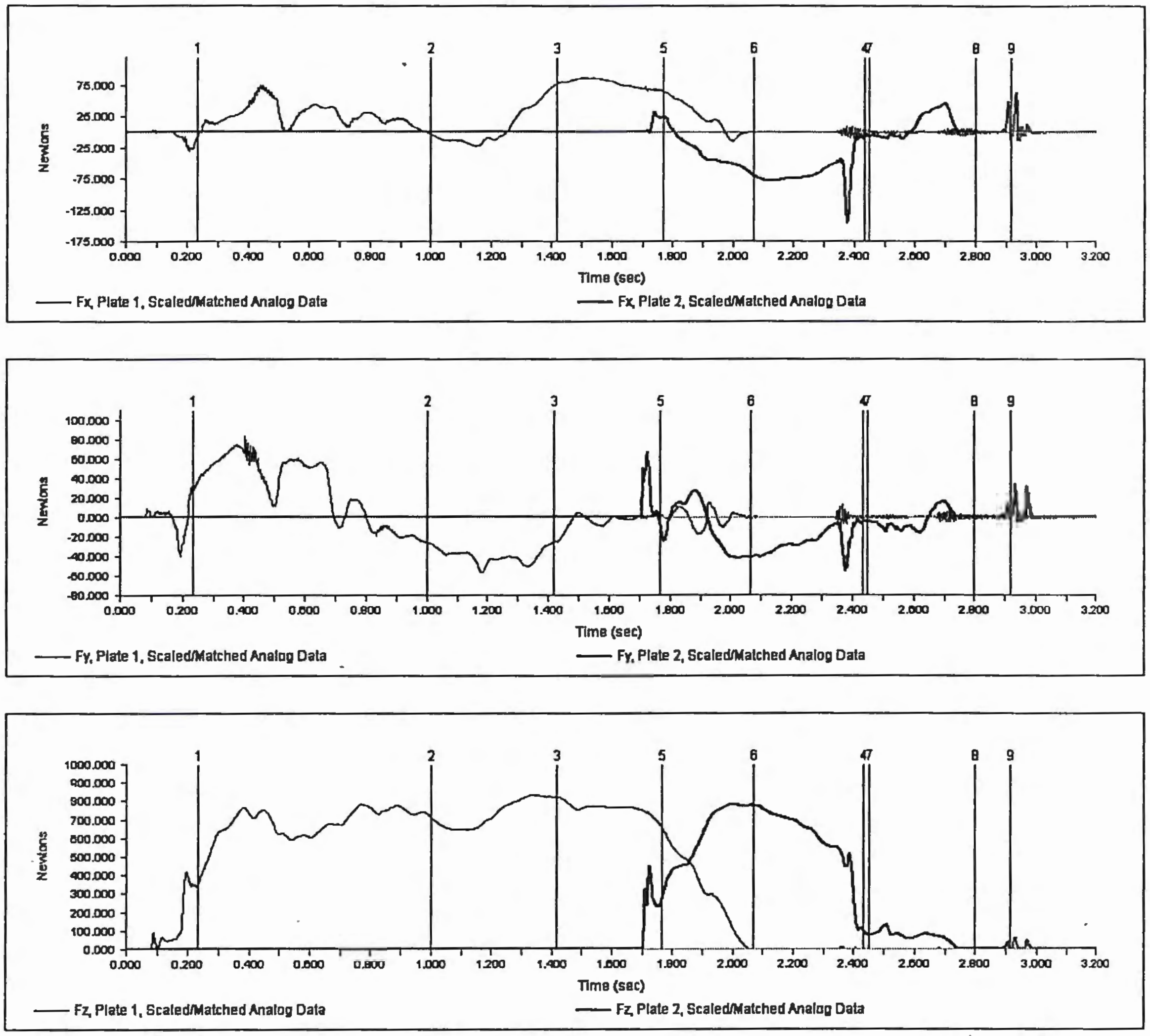


Figure 10. Gait trial under worst conditions (firm slippery surface, carrying weight, rubber boots, and glare light) showing the changes in Fx, Fy, and Fz collected on the force platform.

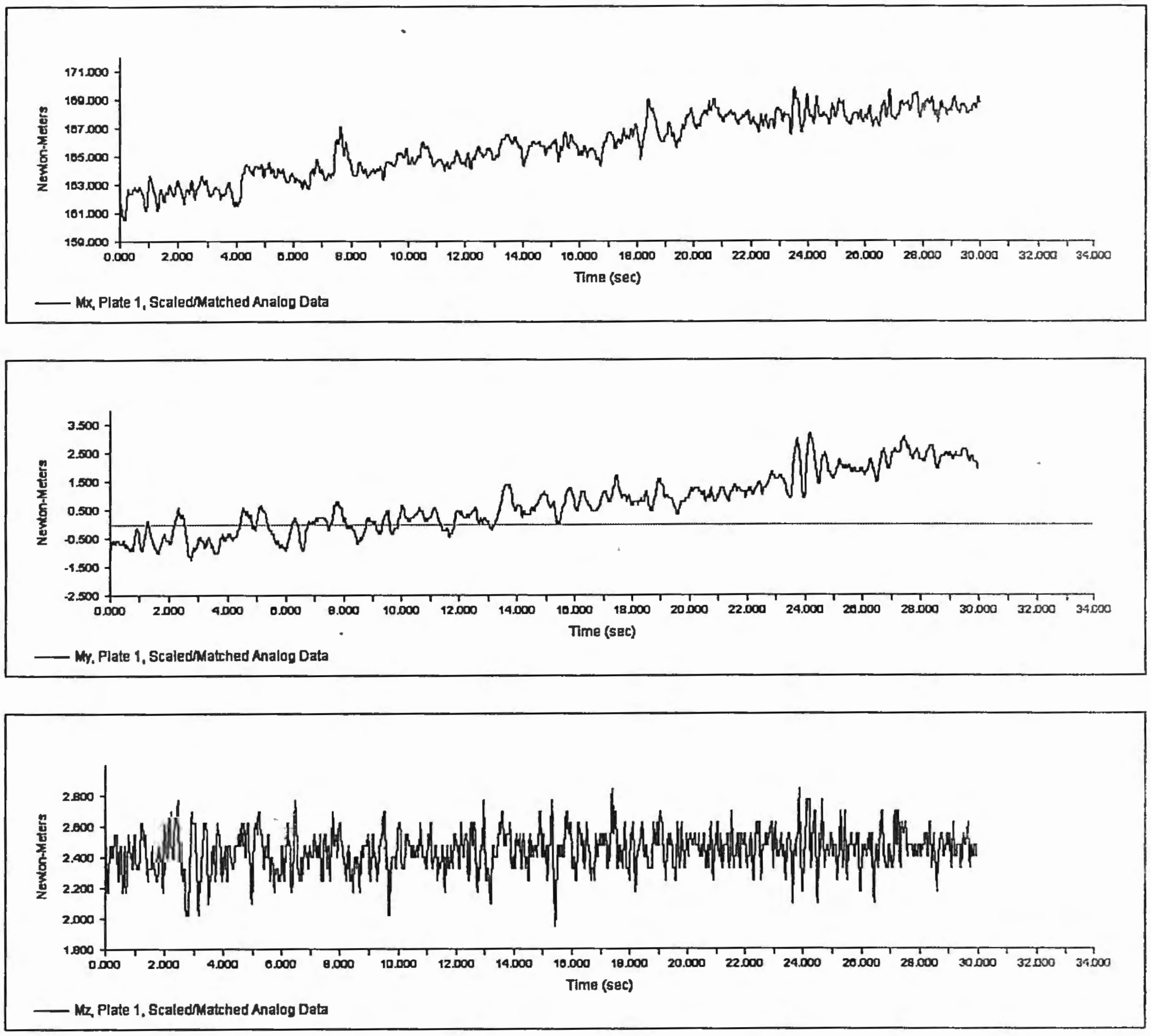


Figure11. Stationary trial under best conditions (firm dry surface, 2-knees position, and poor light) showing the changes in Mx, My, and Mz collected on the force platform.

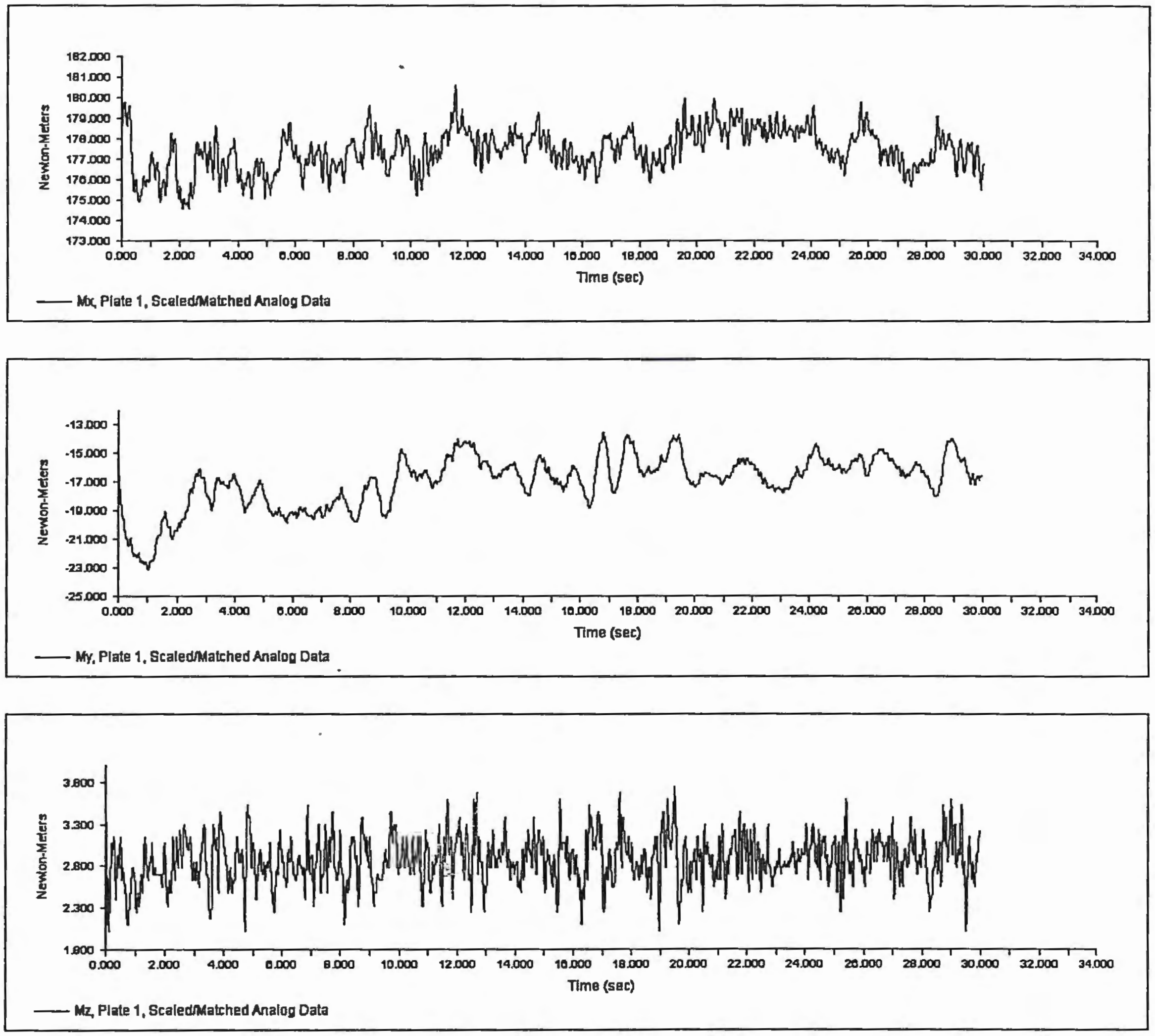


Figure 12. Stationary trial under worst conditions (firm slippery surface, 1-knee position, and glare light) showing the changes in Mx, My, and Mz collected on the force platform.

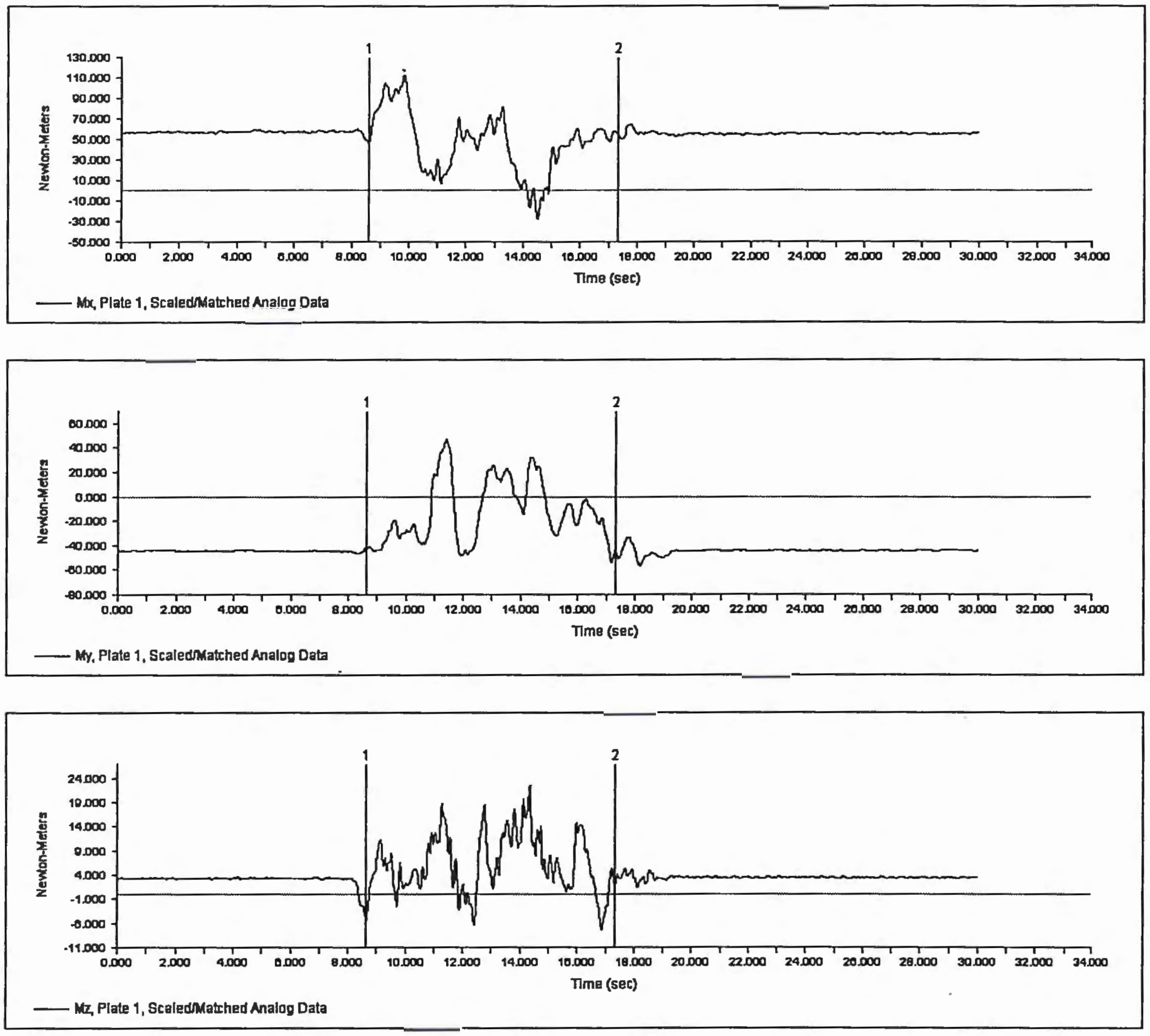


Figure 13. Scaling trial under best conditions (firm dry surface, 2-knees position, and poor light) showing the changes in Mx, My, and Mz collected on the force platform.

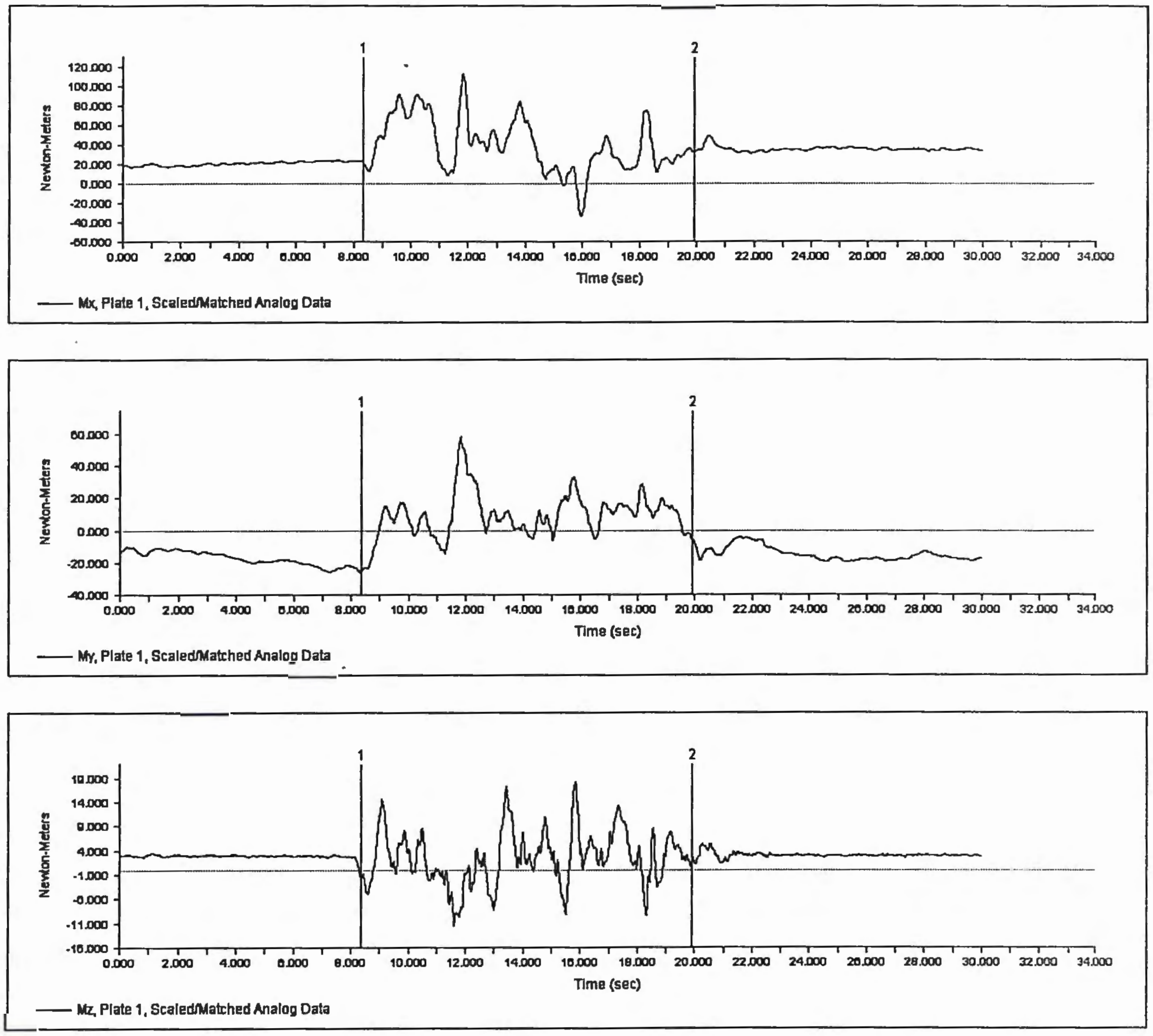


Figure 14. Scaling trial under worst conditions (firm slippery surface, 1-knee position, and glare light) showing the changes in Mx, My, and Mz collected on the force platform.

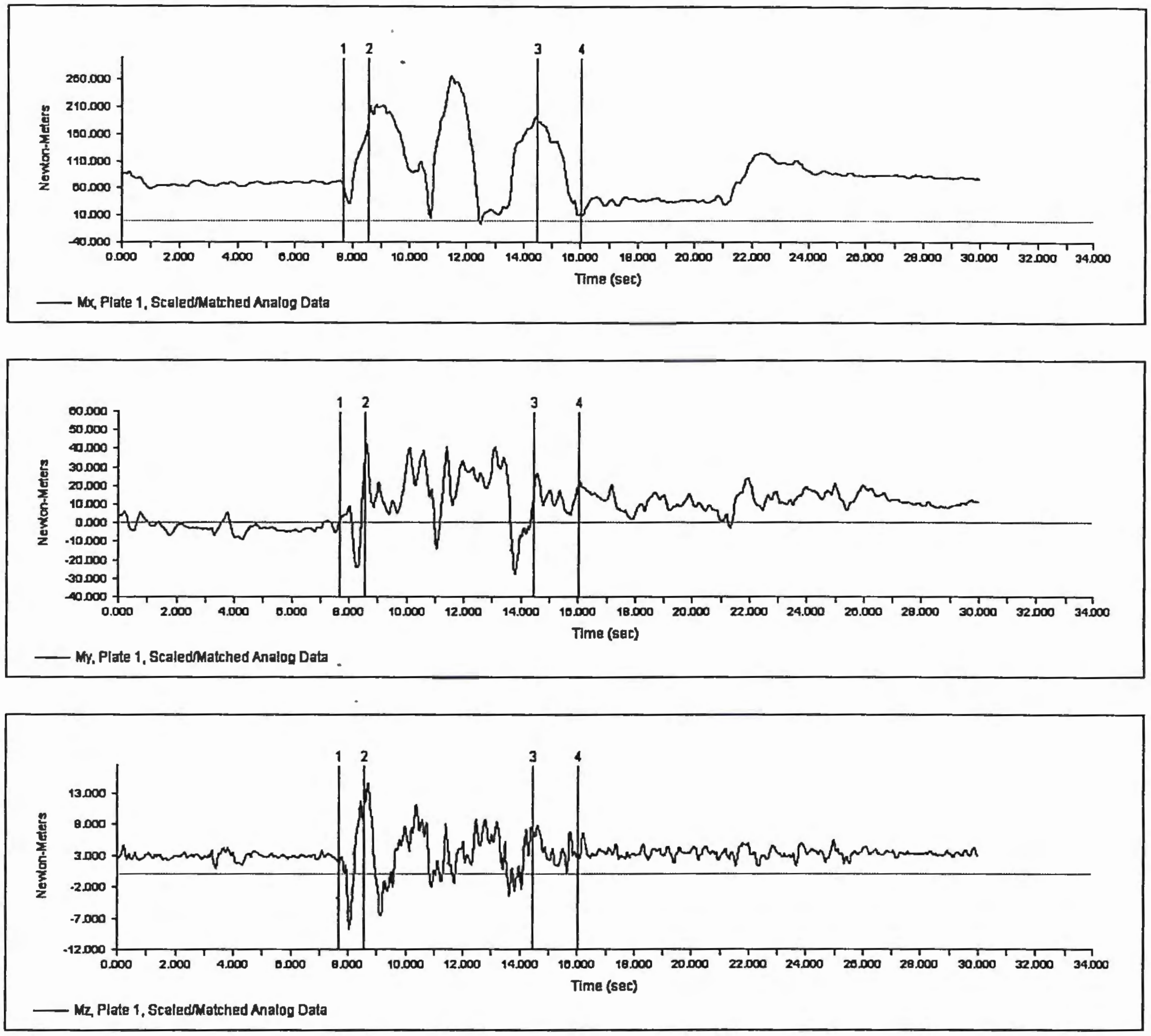


Figure 15. Cable trial under best conditions (firm dry surface, 2-knees position, and poor light) showing the changes in Mx, My, and Mz collected on the force platform.

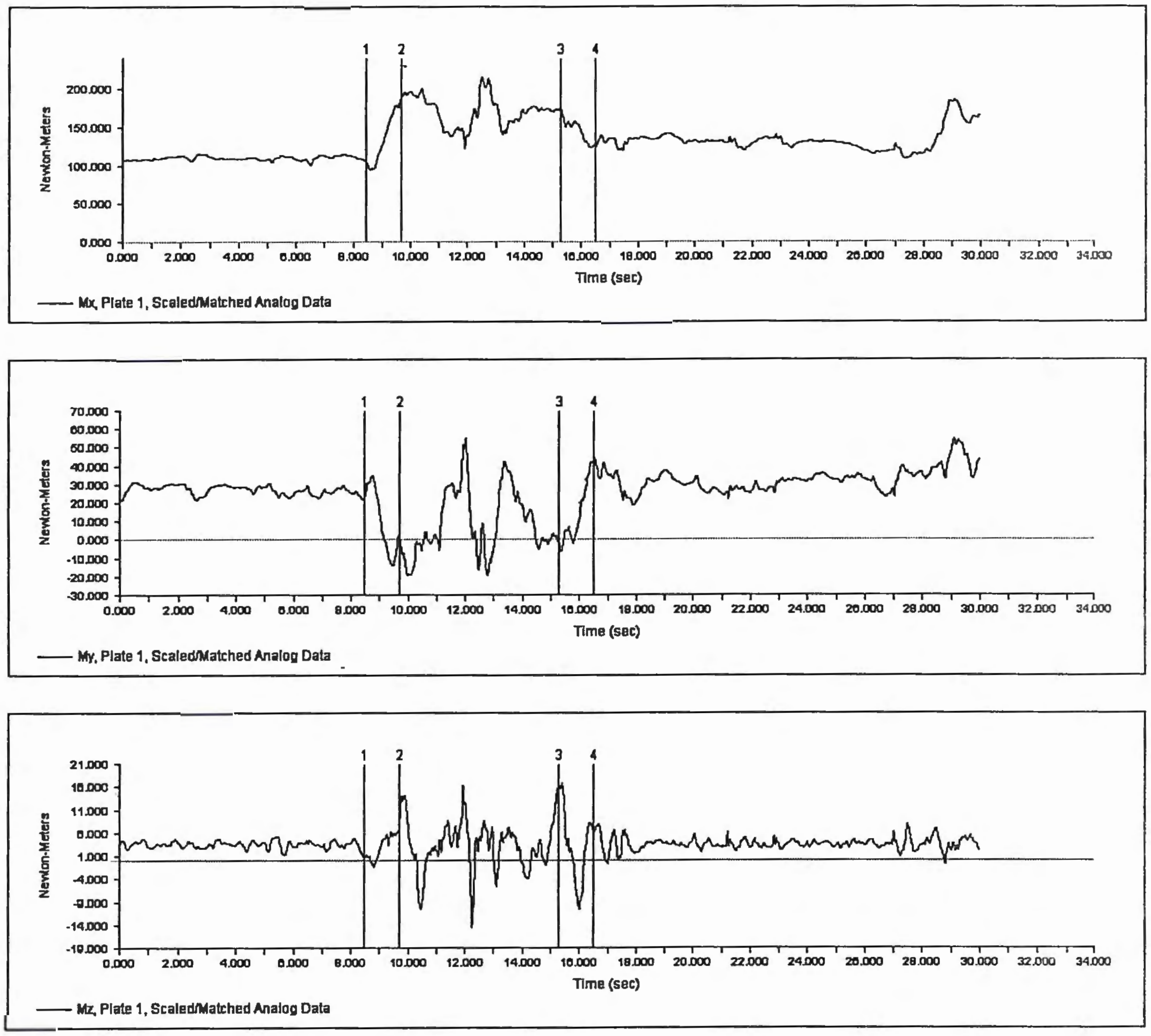


Figure 16. Cable trial under worst conditions (firm slippery surface, 1-knee position, and glare light) showing the changes in Mx, My, and Mz collected on the force platform.

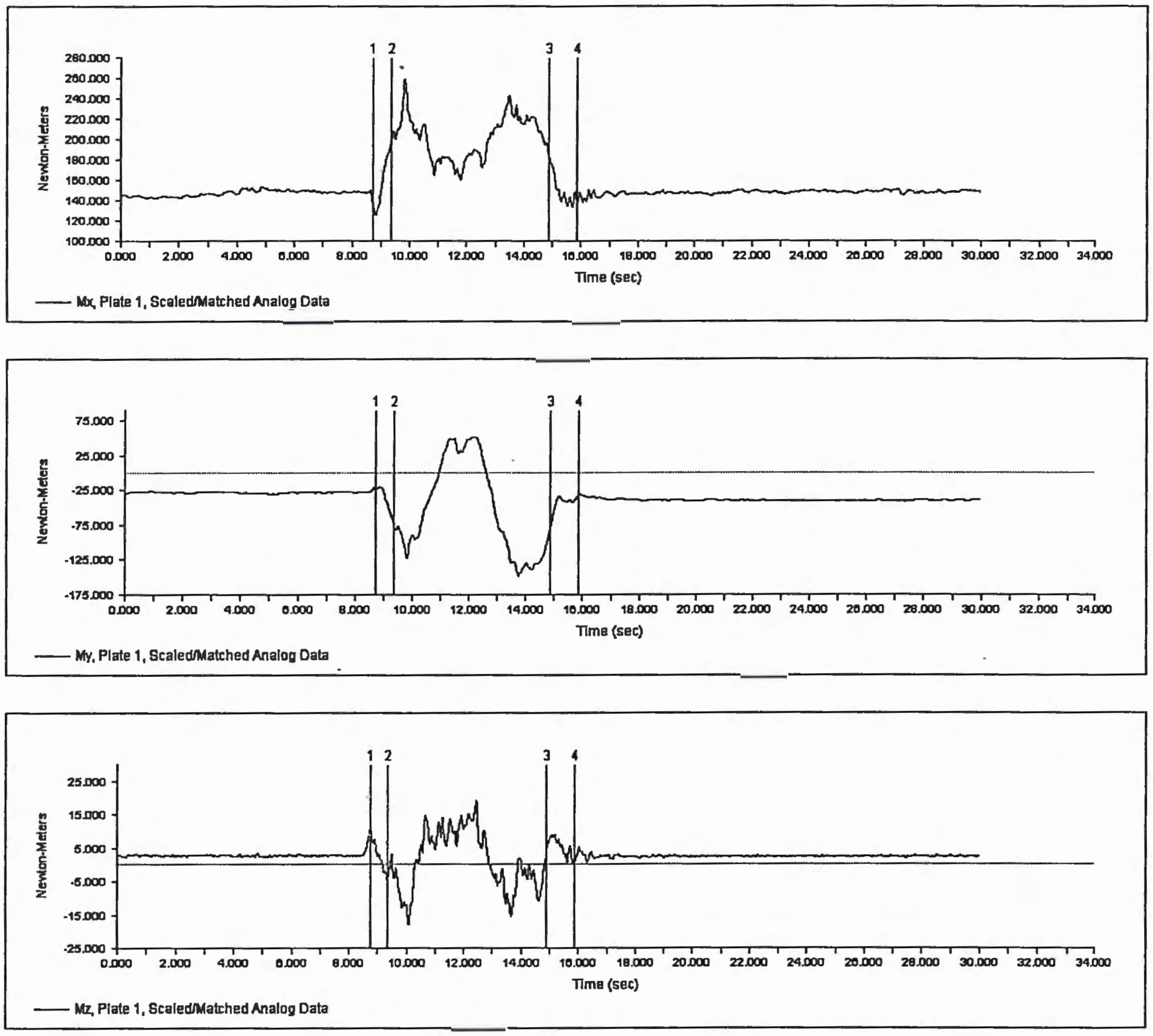


Figure 17. Bits trial under best conditions (firm dry surface, 2-knees position, and poor light) showing the changes in Mx, My, and Mz collected on the force platform.

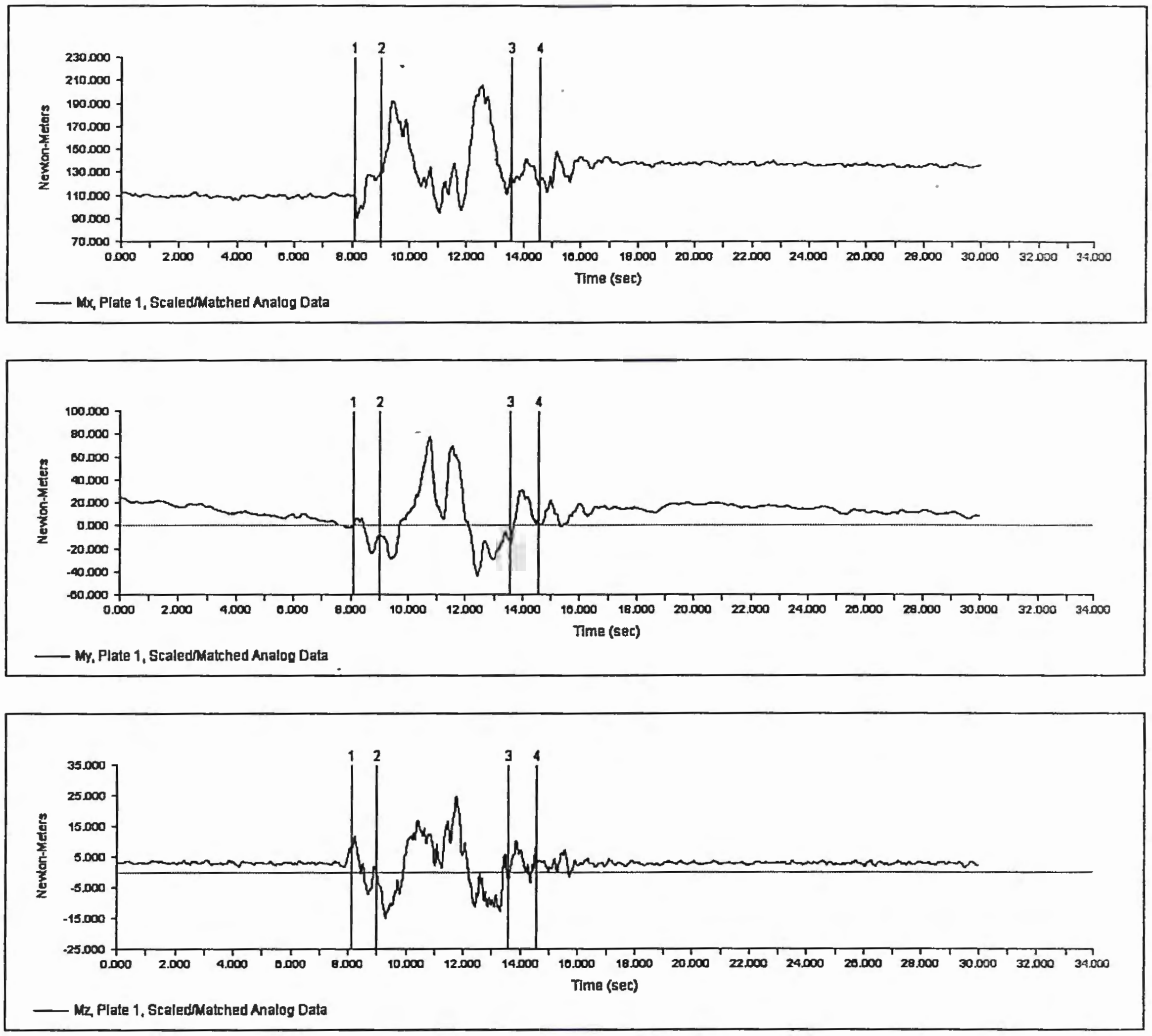


Figure 18. Bits trial under worst conditions (firm slippery surface, 1-knee position, and glare light) showing the changes in Mx, My, and Mz collected on the force platform.

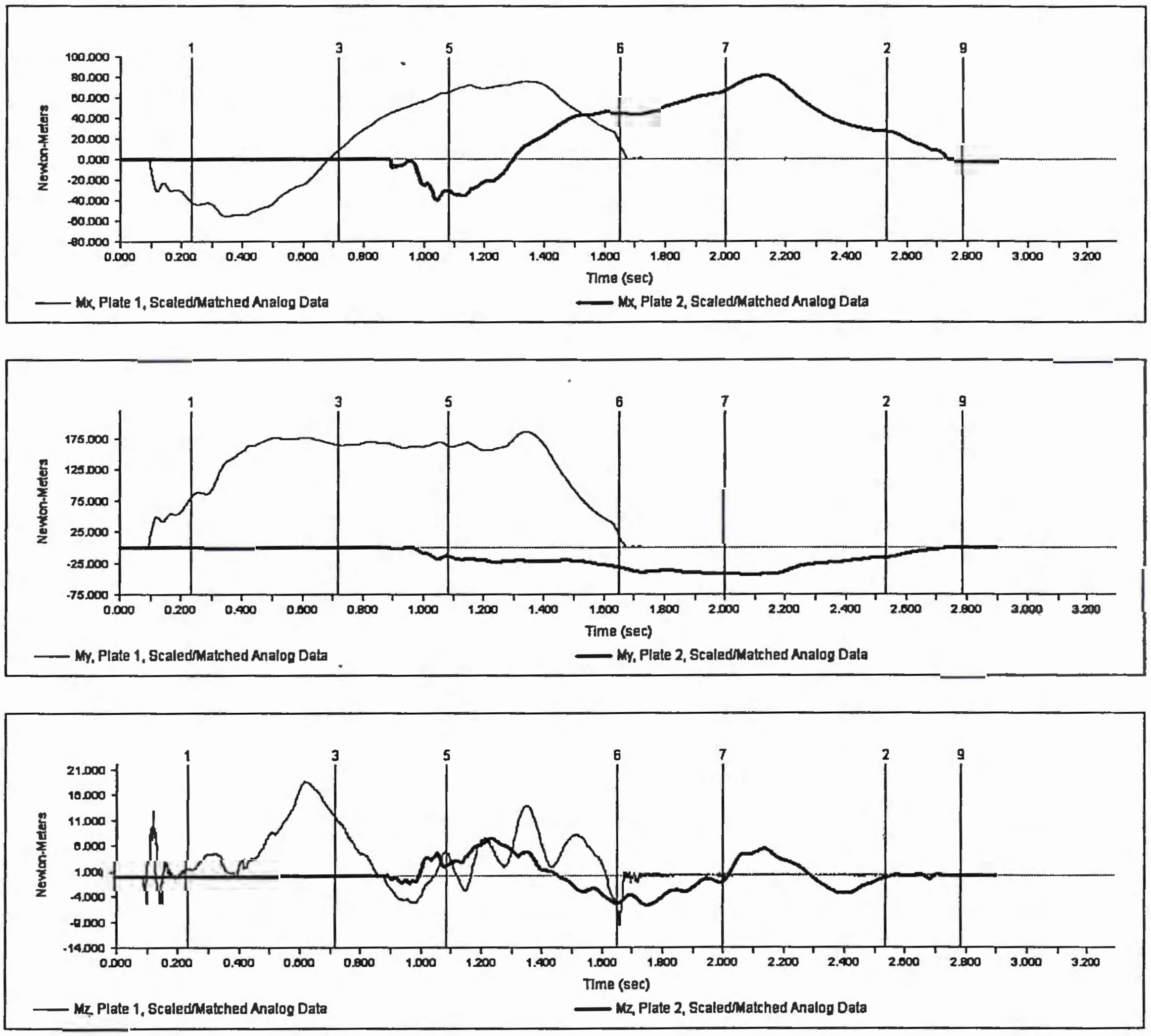


Figure 19. Gait trial under best conditions (firm dry surface, no weight, leather boots, and poor light) showing the changes in Mx, My, and Mz collected on the force platform.

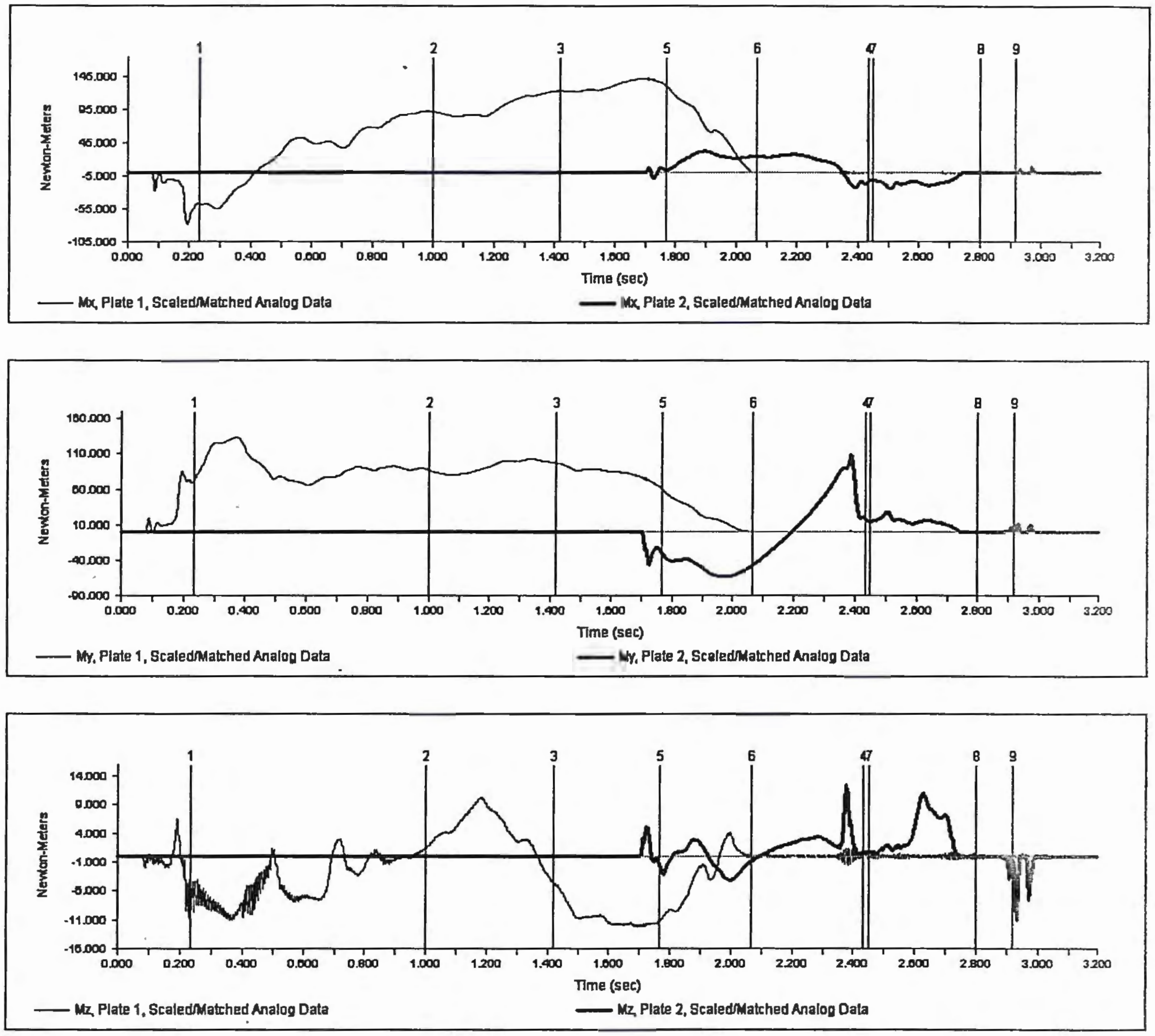
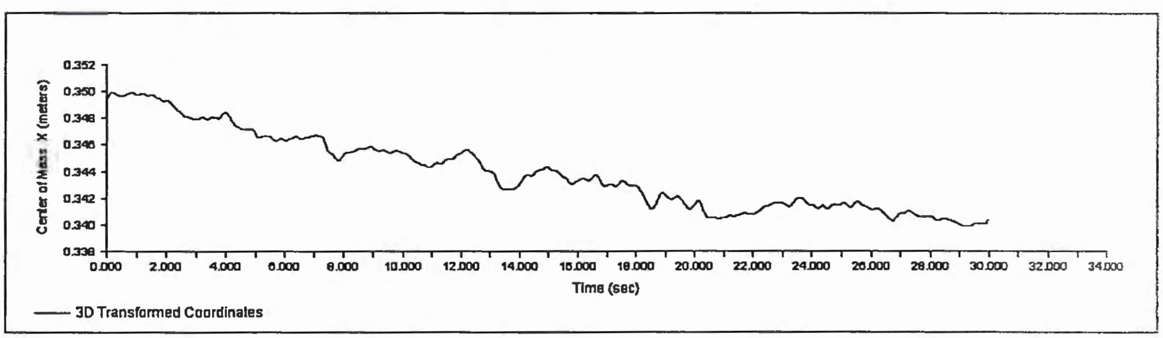
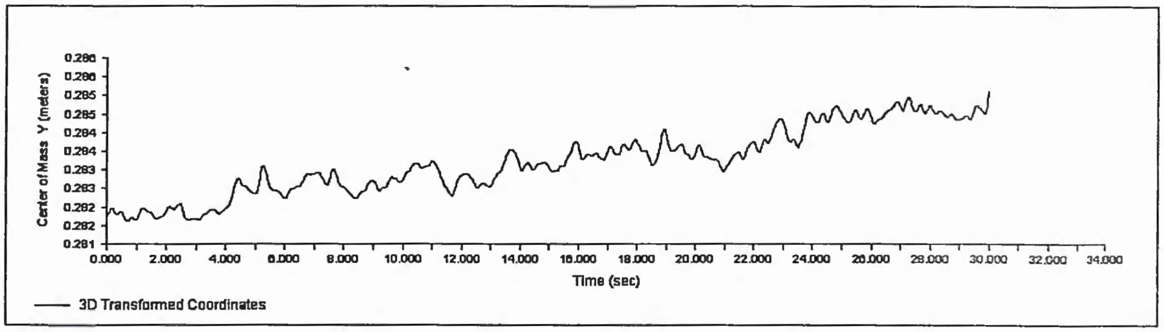


Figure 20. Gait trial under worst conditions (firm slippery surface, carrying weight, rubber boots, and glare light) showing the changes in Mx, My, and Mz collected on the force platform.





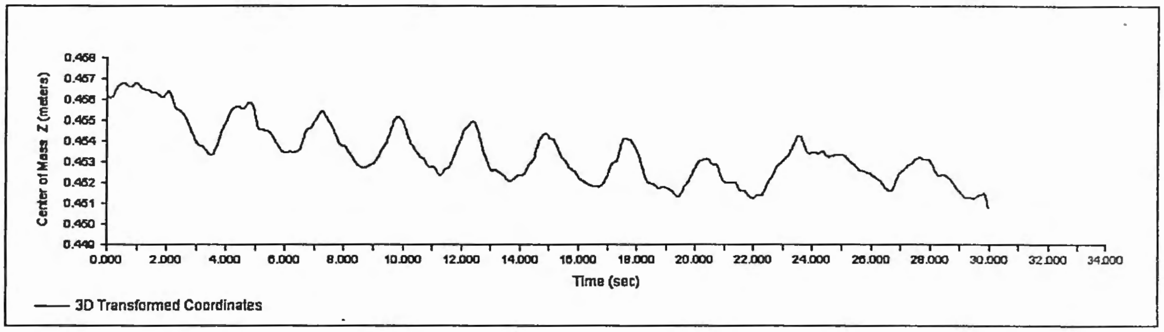


Figure 21(CG plots). Stationary trial under best conditions (firm dry surface, 2-knees position, and poor light) showing the movement of the center of mass (COM) in the Mediolateral (X), Anteroposterior (Y) and up and down (Z) directions.

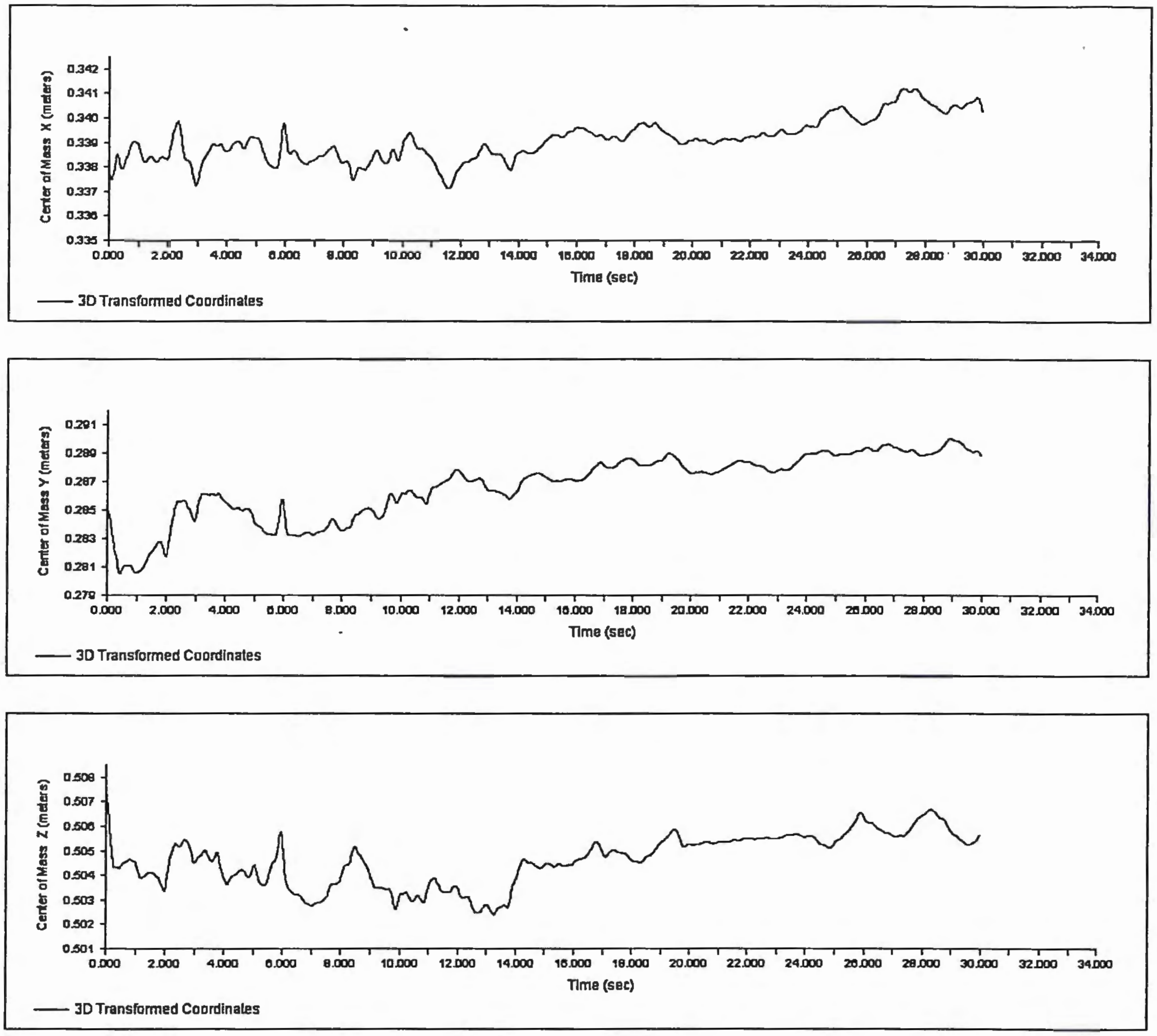


Figure 22. Stationary trial under worst conditions (firm slippery surface, 1-knee position, and glare light) showing the movement of the center of mass (COM) in the Mediolateral (X), Anteroposterior (Y) and up and down (Z) directions.

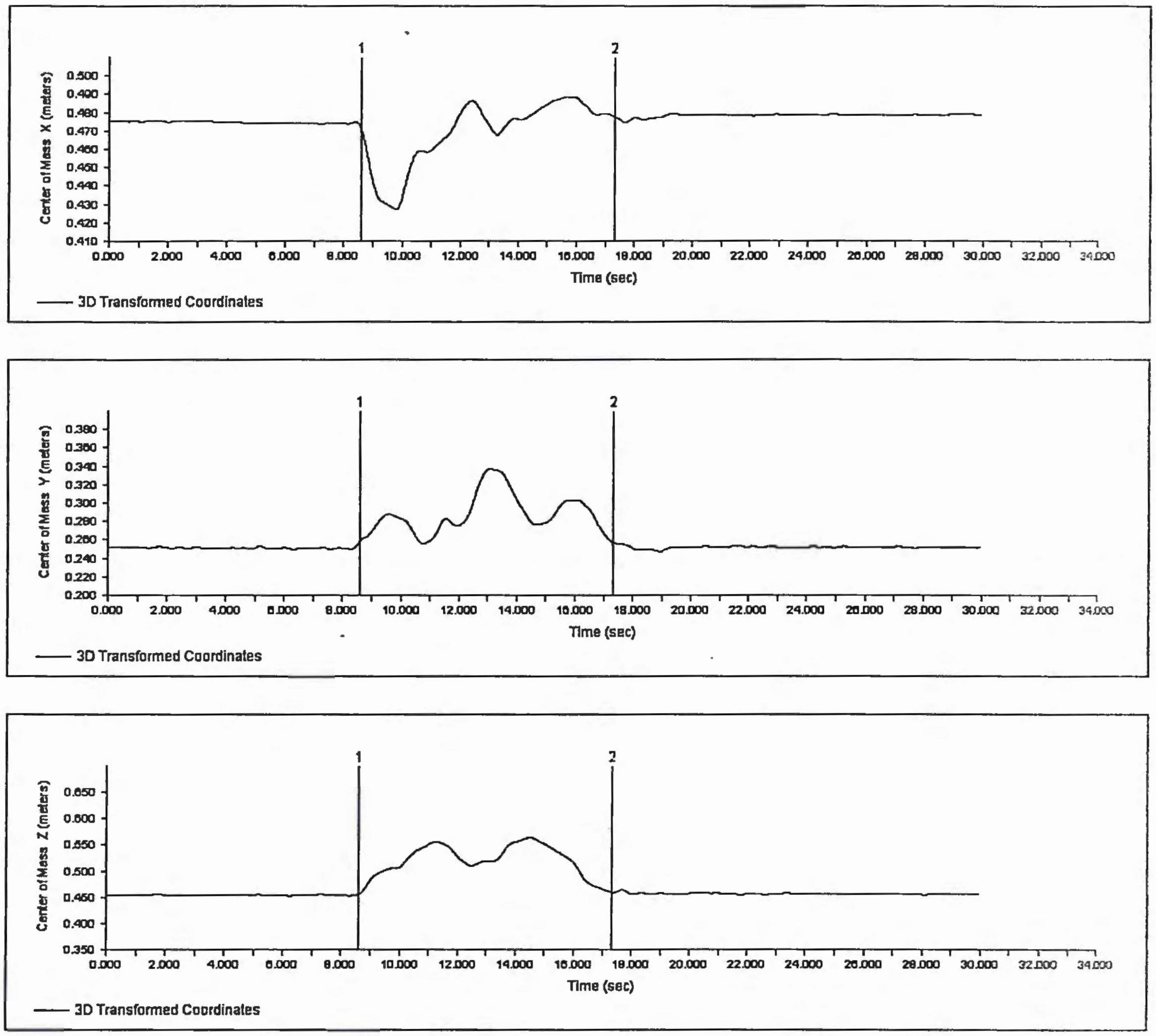


Figure 23. Scaling trial under best conditions (firm dry surface, 2-knees position, and poor light) showing the movement of the center of mass (COM) in the Mediolateral (X), Anteroposterior (Y) and up and down (Z) directions.

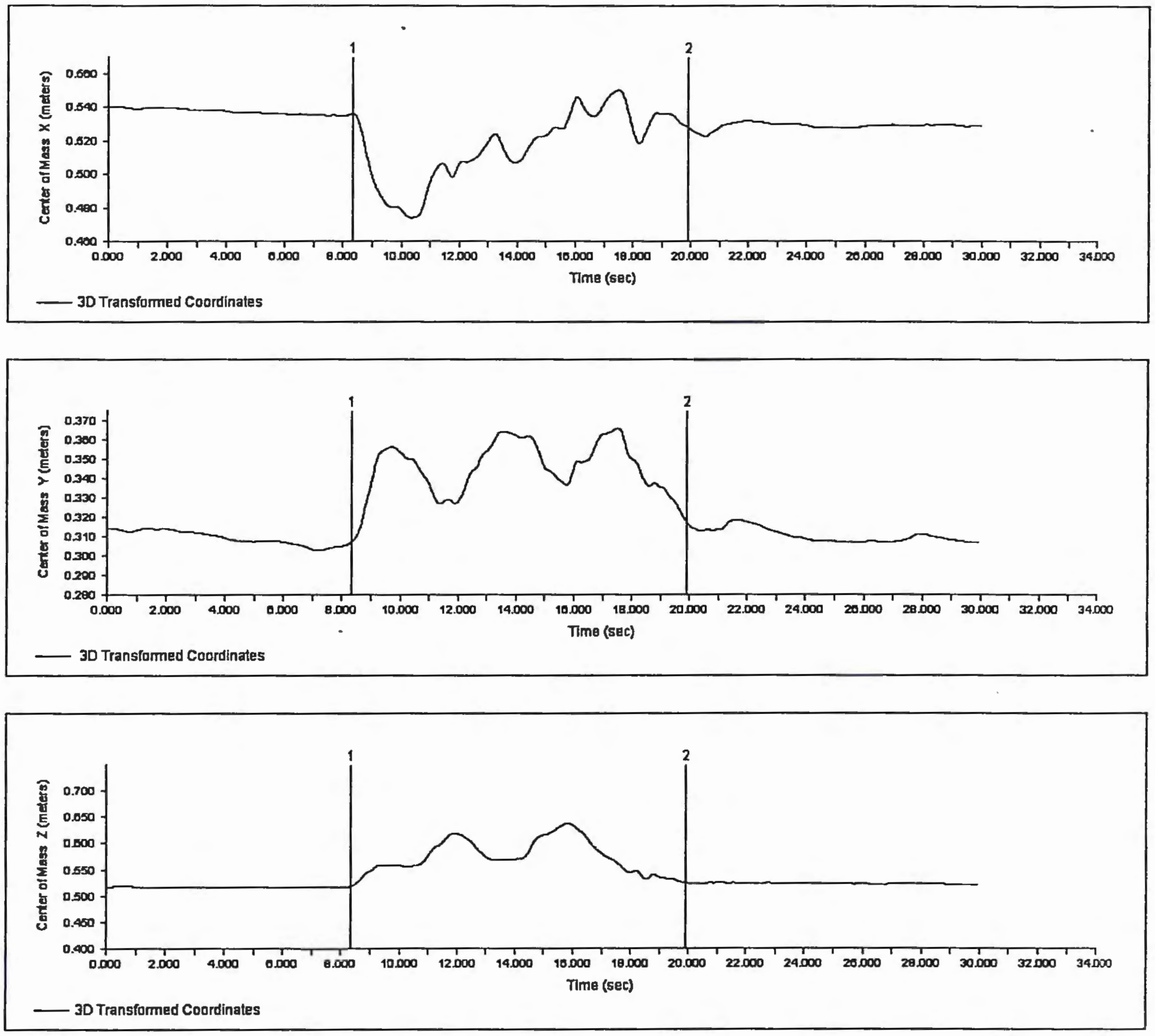


Figure 24. Scaling trial under worst conditions (firm slippery surface, 1-knee position, and glare light) showing the movement of the center of mass (COM) in the Mediolateral (X), Anteroposterior (Y) and up and down (Z) directions.

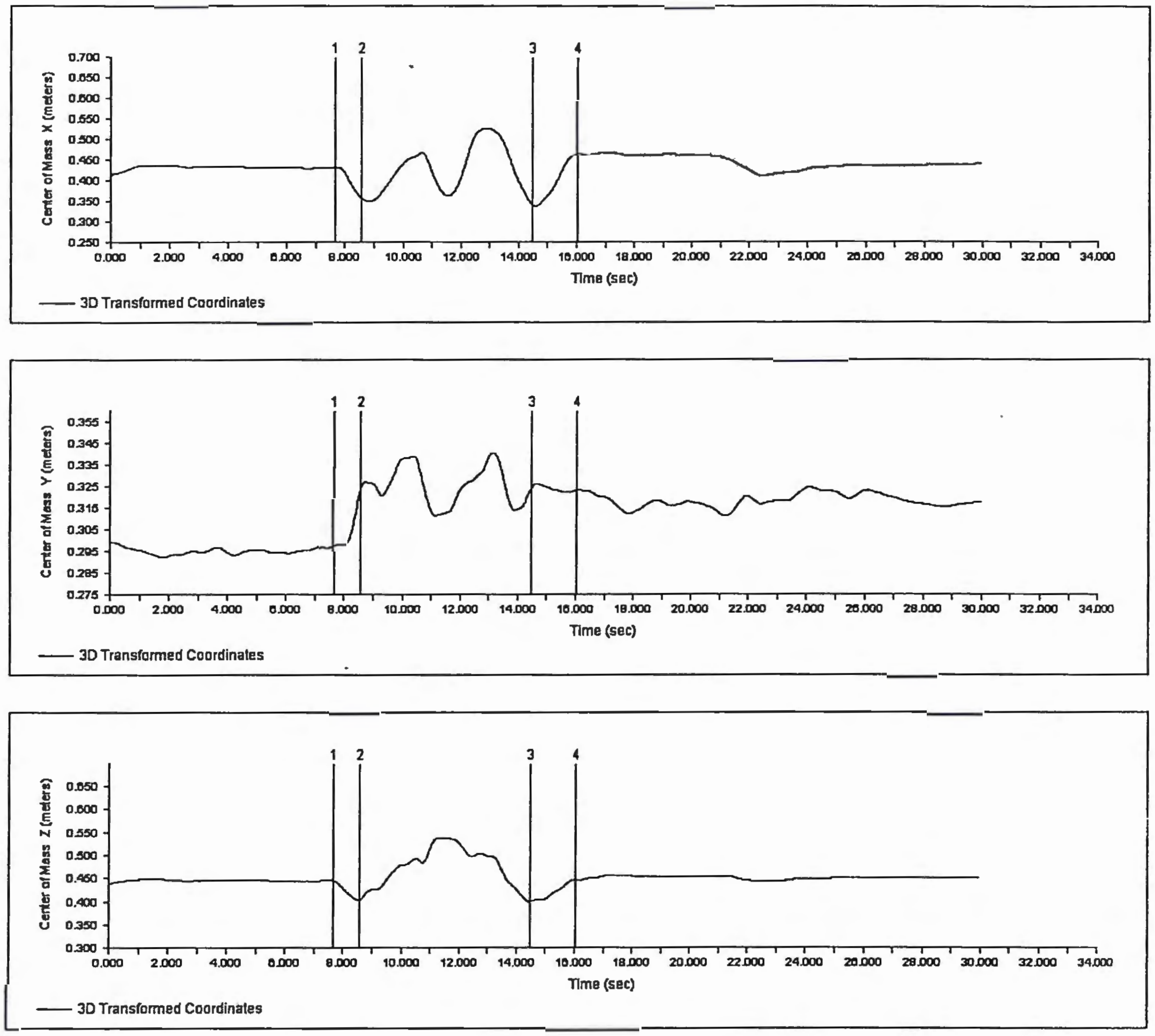


Figure 25. Cable trial under best conditions (firm dry surface, 2-knees position, and poor light) showing the movement of the center of mass (COM) in the Mediolateral (X), Anteroposterior (Y) and up and down (Z) directions.

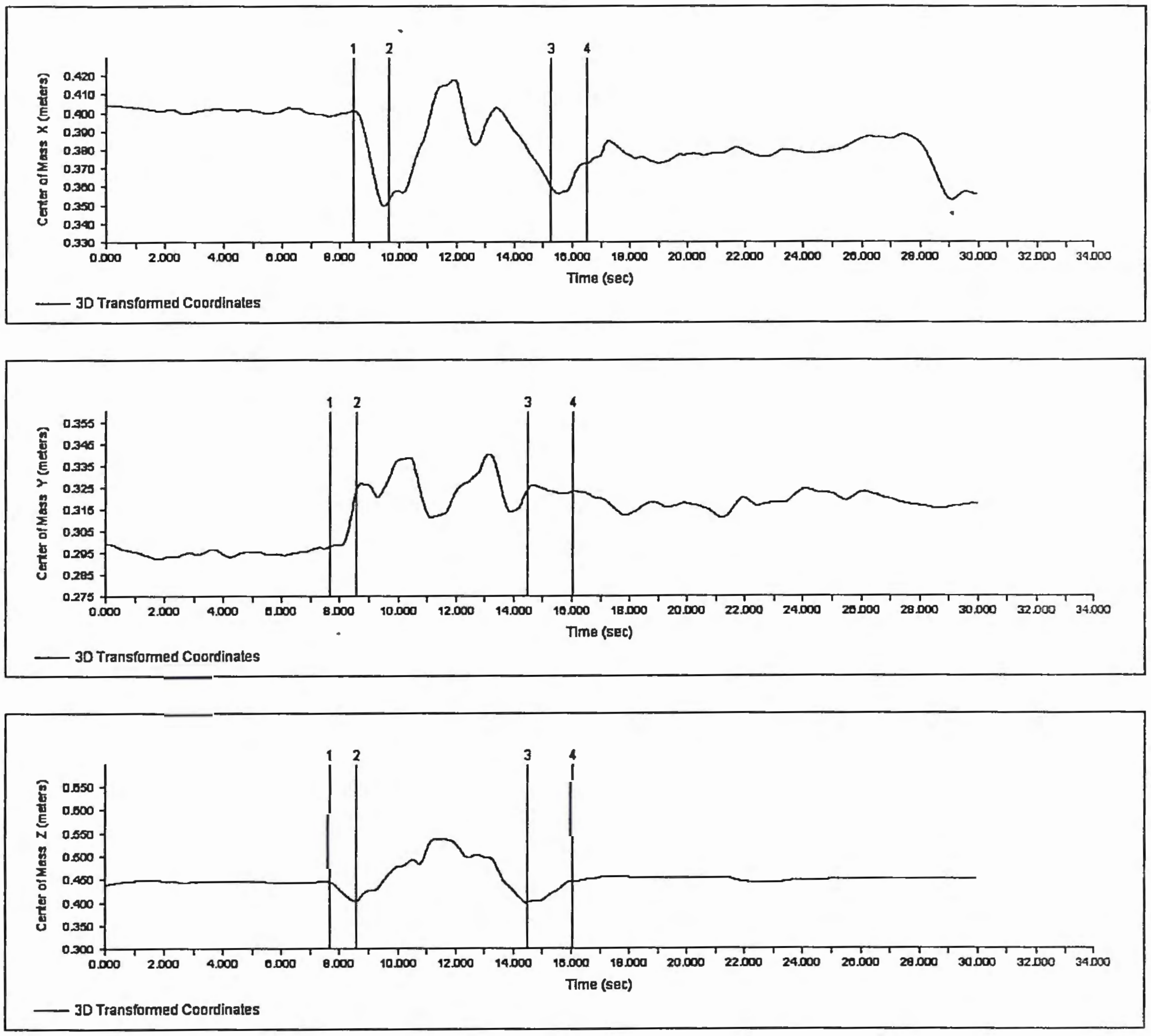


Figure 26. Cable trial under worst conditions (firm slippery surface, 1-knee position, and glare light) showing the movement of the center of mass (COM) in the Mediolateral (X), Anteroposterior (Y) and up and down (Z) directions.

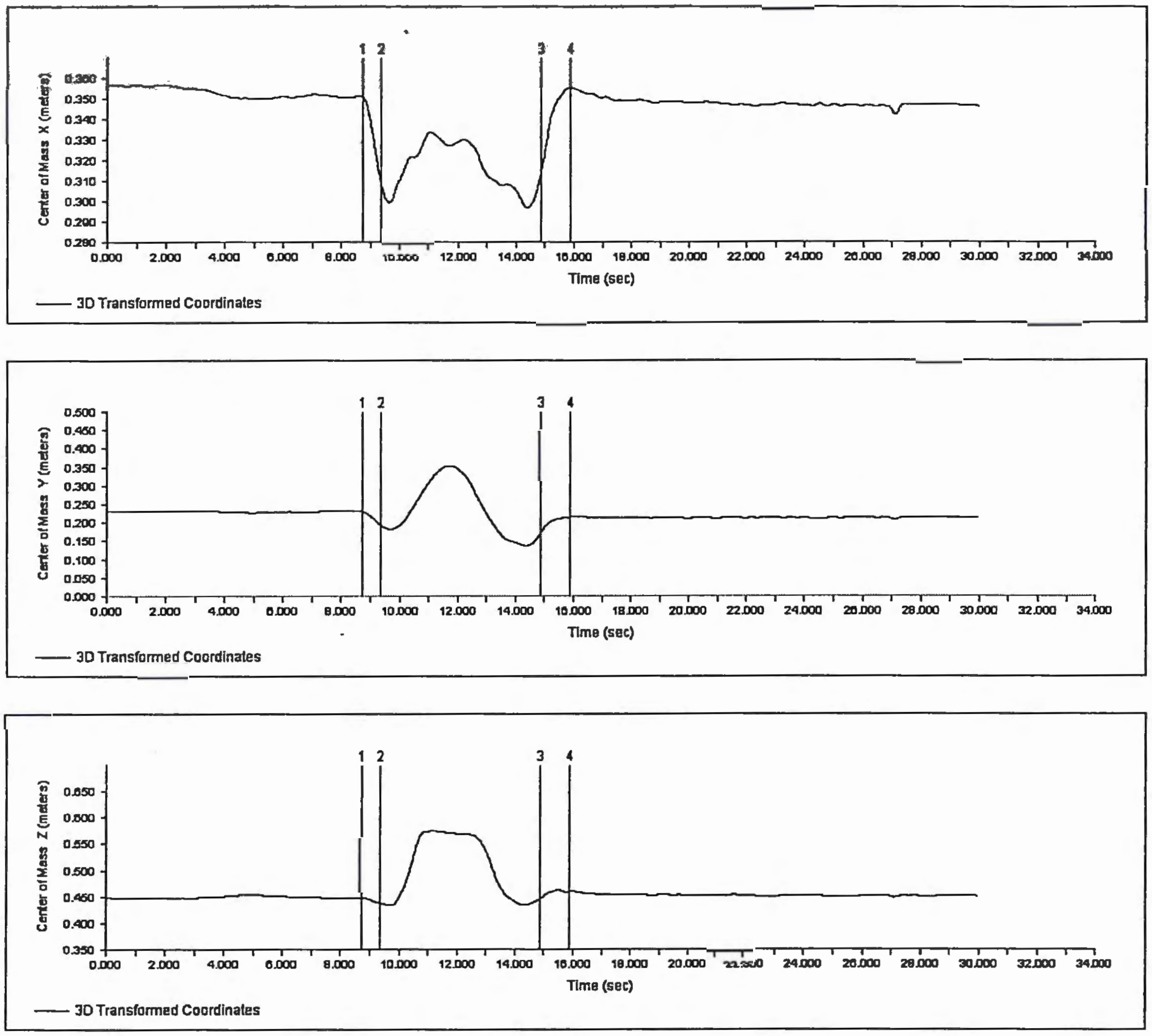


Figure 27. Bits trial under best conditions (firm dry surface, 2-knees position, and poor light) showing the movement of the center of mass (COM) in the Mediolateral (X), Anteroposterior (Y) and up and down (Z) directions.

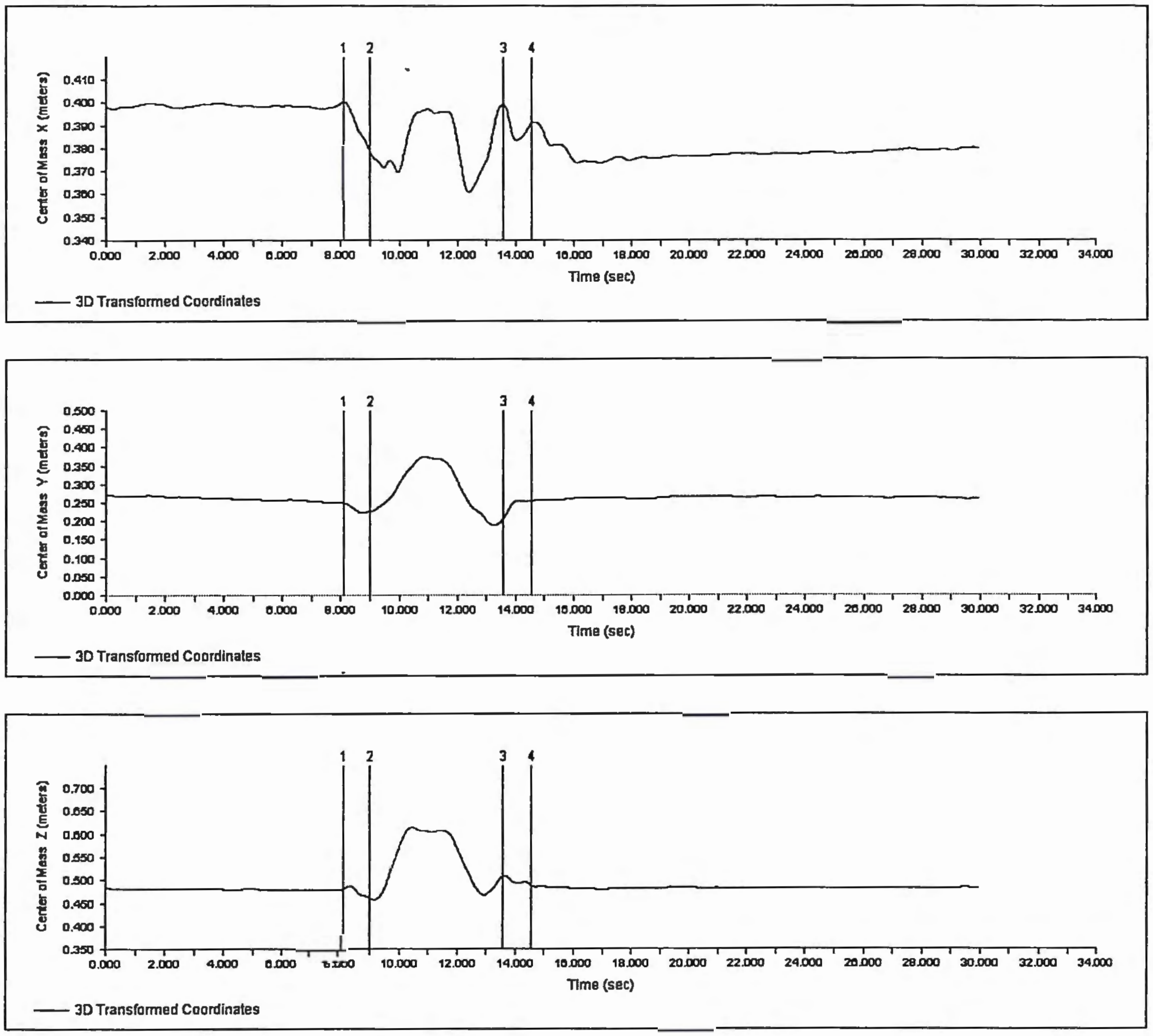


Figure 28. Bits trial under worst conditions (firm slippery surface, 1-knee position, and glare light) showing the movement of the center of mass (COM) in the Mediolateral (X), Anteroposterior (Y) and up and down (Z) directions.

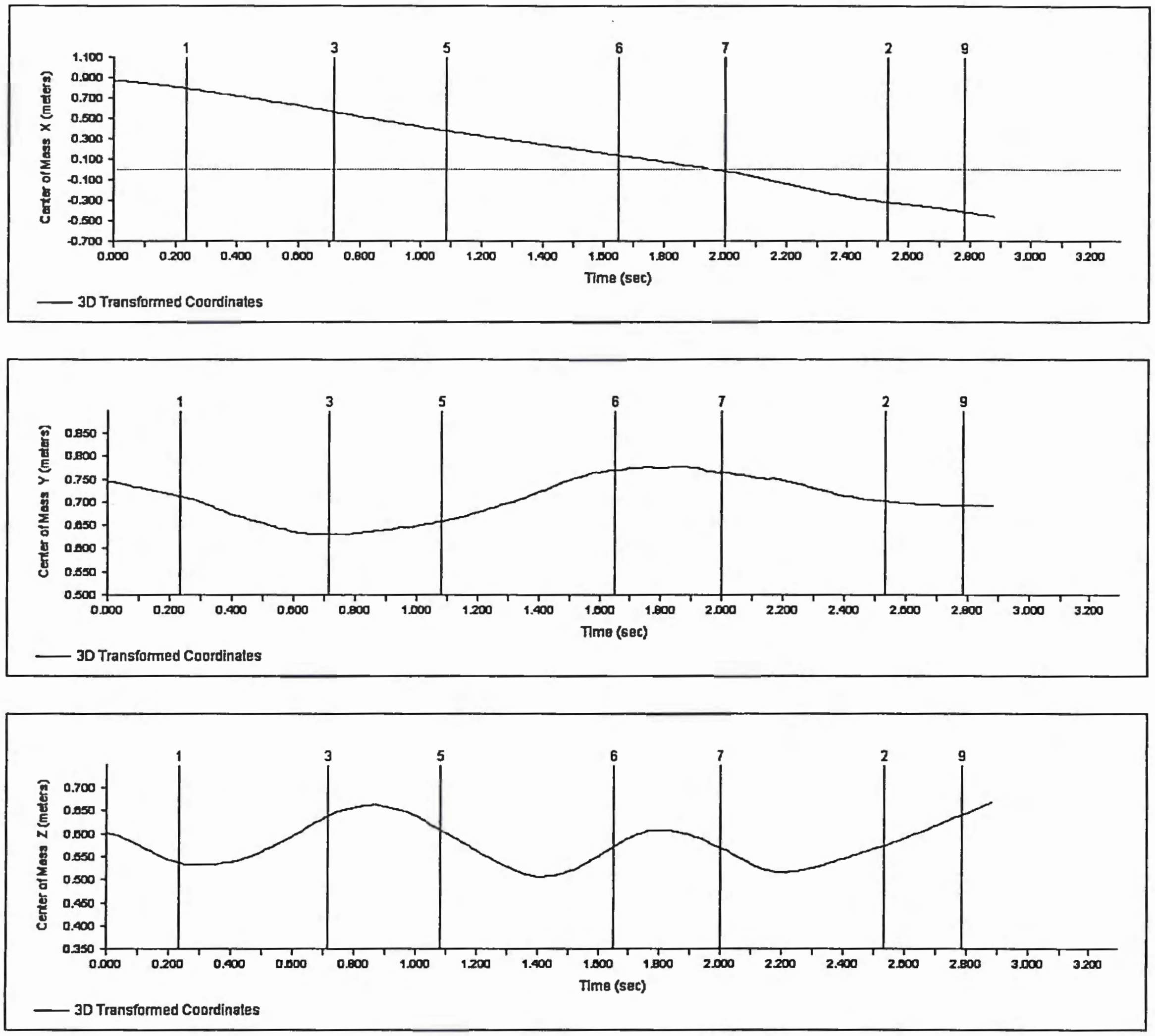


Figure 29. Gait trial under best conditions (firm dry surface, no weight, leather boots, and poor light) showing the movement of the center of mass (COM) in the Mediolateral (X), Anteroposterior (Y) and up and down (Z) directions.

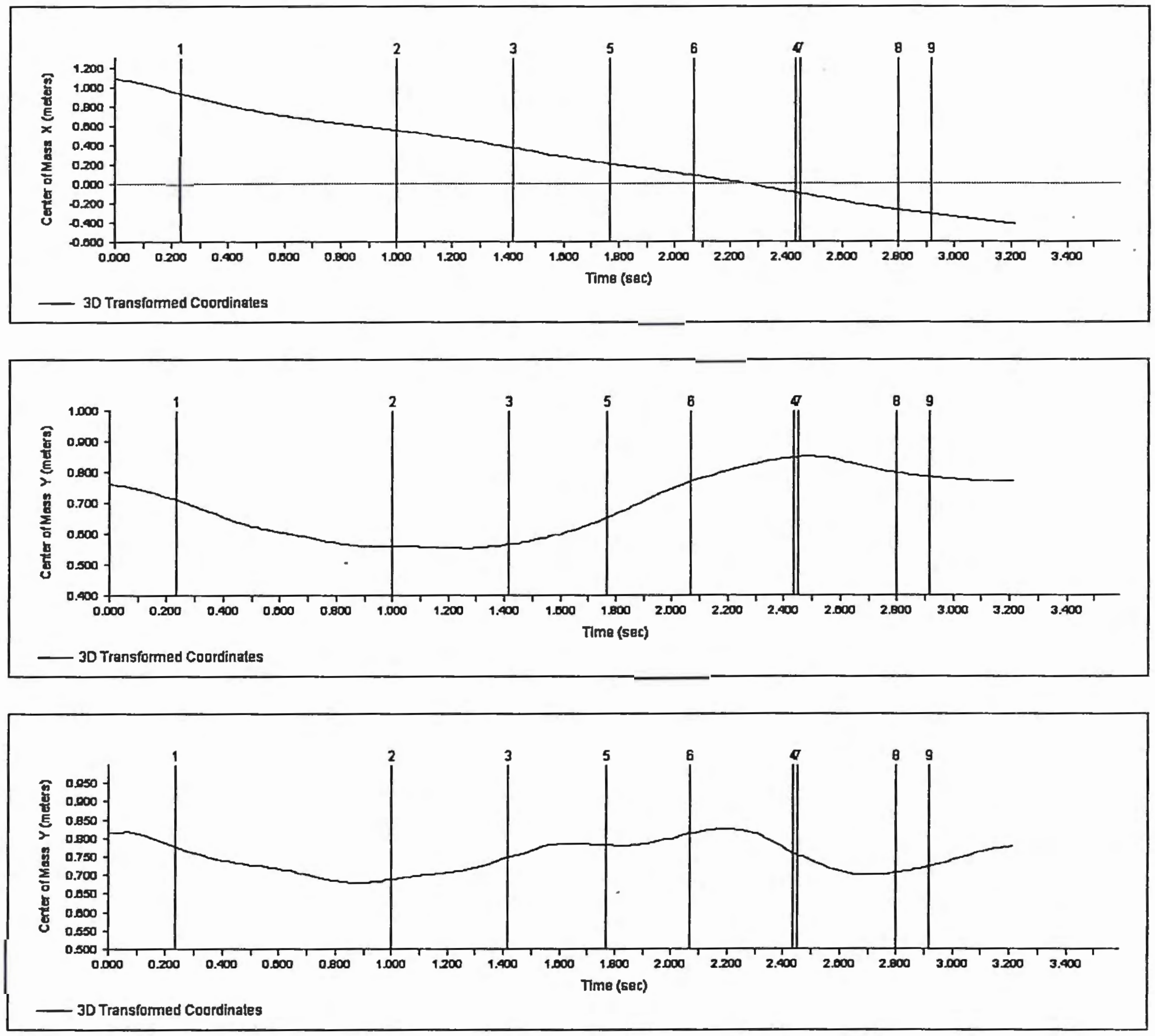


Figure 30. Gait trial under worst conditions (firm slippery surface, carrying weight, rubber boots, and glare light) showing the movement of the center of mass (COM) in the Mediolateral (X), Anteroposterior (Y) and up and down (Z) directions.

APPENDIX O

List of Outcome variables and covariates used in statistical models

MINING DATA DICTIONARY FOR VARIABLES AND COVARIATES USED IN STATISTICAL MODELS

M =MAIN
O =OUTCOME VARIABLE
C =COVARIATE

		COLUMN NAME	DESCRIPTION	UNITS
Balance				
Kinelysis		ID	Subject Identification	alpha numeric
		Sequence	Sequence order of trials	numeric
	M	Task and posture	A=stat1knee, B=stat2knee, C=cable1knee, D=cable2knee, E=bits1knee, F=bits2knee G=scaling1knee, H=scaling2knee	alpha
	M	Surface and ceiling	J=firm dry 44", L=uneven dry 44", N=firm slippery 44"	alpha
	M	lighting	P=poor, R=glare	alpha
	M	footwear	S=shoe, T=boot	alpha
	O	SA	Sway Area from Kinelysis	sq cm
	O	SL	Sway Length from Kinelysis	cms
	O	Excurx	Excursion X from Kinelysis	cms
	O	Excury	Excursion Y from Kinelysis	cms
	O	MinHV	Minimum H/V	numeric
	O	MaxHV	Maximum H/V	numeric
Balance				
posture60		ID	Subject Identification	alpha numeric
		Sequence	Sequence order of trials	numeric
	M	Task and posture	A=stat1knee, B=stat2knee, C=cable1knee, D=cable2knee, E=bits1knee, F=bits2knee G=scaling1knee, H=scaling2knee	alpha
	M	Surface and ceiling	J=firm dry 44", L=uneven dry 44", N=firm slippery 44"	alpha
	M	lighting	P=poor, R=glare	alpha
	M	footwear	S=shoe, T=boot	alpha
	O	SA_P60	Sway Area from Posture 60	sq cm
	O	SL_P60	Sway Length from Posture60	cms
IPSB		FILENAME	Name of the file	alpha numeric
	O	IPSB_min	Index of proximity to stability boundary (minimum)	numeric
	O	IPSB_avg	Index of proximity to stability boundary (average)	numeric
	O	IPSB_max	Index of proximity to stability boundary (maximum)	numeric
	O	IPSB_rms	Index of proximity to stability boundary (root mean squared)	numeric
	O	WRTI	Weighted residence time index	numeric
	O	SAR	Stability Area Ratio	numeric

MINING DATA DICTIONARY FOR VARIABLES AND COVARIATES USED IN STATISTICAL MODELS

M =MAIN
O =OUTCOME VARIABLE
C =COVARIATE

0-2

Anthrodata1		ID	Subject identification	Alpha Numeric
		DATE	Date Of Visit	Date
		GENDER	M-male ,F-Female	Alpha
		DOB	Date Of Birth	Date
		HGT	Height	cms
		WT	Weight	kgs
		SHOE	Shoe Size	US standards
		RFL	Right Foot Length	cms
		RFW	Right Foot Width	cms
		LFL	Left Foot Length	cms
		LFW	Left Foot Width	cms
		LL	Leg Length	cms
		AL	Arm Length	cms
		TRC	Trunk Circumference	cms
		KH	Knee Height	cms
		SH	Shoulder Height	cms
		EH	Elbow Height	cms
		FFR	Forward Functional Research	cms
		LAL	Left Arm Lateral Functional Reach	cms
		RAL	Right Arm Lateral Functional Reach	cms
		ARM_FT	Arm/Foot Tested R-right, L-Left	Alpha
	C	ART_1	Arm Reaction Time 1	mili seconds
	C	ART_2	Arm Reaction Time 2	mili seconds
	C	ART_3	Arm Reaction Time 3	mili seconds
	C	FRT_1	Foot Reaction Time 1	mili seconds
	C	FRT_2	Foot Reaction Time 2	mili seconds
	C	FRT_3	Foot Reaction Time 3	mili seconds
		RACE	1-White,2-Black/African American,3-Hispanic,4-Native American Or Alaskan Native,5-Asian O	Numeric
		EDUC	1-Less Than 12th,2-High School Grad,3-Undergraduate Degree,4-Graduate Degree.5-Some C	Numeric
		LIV_ARG	1-Alone,2-With Spouse Or Partner,3-With Child Or Family,4- Other	Numeric

MINING DATA DICTIONARY FOR VARIABLES AND COVARIATES USED IN STATISTICAL MODELS

M =MAIN
O =OUTCOME VARIABLE
C =COVARIATE

	ID	subject identification	alpha numeric
	DATE	Day of Visit	date
	LOCATION	Location of testing (M=Middlesboro/Field, C=Cincinnati/Lab)	alpha
	TYPE	Type of testing (B=balance, G=gait, or BG=balance and gait)	alpha
	SESSION	SESSION NUMBER	Numeric
C	WORK	HAVE YOU WORKED IN LAST 24 HRS 0=NO 1=YES	Numeric
	HR_W	HOURS WORKED IN CURRENT/PREVIOUS SHIFT	Numeric
C	SHIFT	SHIFT CHANGE IN LAST WEEK 0=NO 1=YES	Numeric
C	PE_LEV	PHYSICAL EFFORT LEVEL (ON A SCALE OF 6-20)	Numeric
C	PRE_DIS	PRE TESTING DISCOMFORT 0=NO 1=YES IF YES (WEIGH ON A SCALE OF 0-3) FOR 21 I	Numeric
	Pre_1	**NECK** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_2	**UPPER BACK** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_3	**LEFT SHOULDER** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_4	**RIGHT SHOULDER** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_5	**LEFT UPPER ARM** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_6	**RIGHT UPPER ARM** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_7	**BUTTOCKS** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_8	**MID TO LOWER BACK** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_9	**LEFT FOREARM** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_10	**RIGHT FOREARM** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_11	**LEFT WRIST** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_12	**RIGHT WRIST** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_13	**LEFT HAND** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_14	**RIGHT HAND** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_15	**HIPS/WAIST** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_16	**LEFT THIGH** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_17	**RIGHT THIGH** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_18	**KNEES** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_19	**RIGHT LOWER LEG/FOOT** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3	Numeric
	Pre_20	**LEFT LOWER LEG/FOOT** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Pre_21	**ANKLES** PRE TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
C	SLEEP	TIME USE 24 HRS CLOCK	time
C	WOKE	TIME USE 24 HRS CLOCK	time

MINING DATA DICTIONARY FOR VARIABLES AND COVARIATES USED IN STATISTICAL MODELS

M =MAIN
O =OUTCOME VARIABLE
C =COVARIATE

DOV-1

	NIGHT	DID YOU SLEEP ALL NIGHT 0=NO 1=YES	Numeric
C	MEAL	NUMBER OF HRS SINCE LAST MEAL	Numeric
	CAFF	DID YOU HAVE CAFFEINE IN LAST 12 HRS 0=NO 1=YES	Numeric
	CAFF_TYPE	TYPE OF CAFFEINE (1-COFFEE. 2-TEA, 3-SODA, 4-COCOA, 5-COMBO, 6-NONE)	Numeric
	CAFF_AMT	AMOUNT CONSUMPED IN OUNCES	Numeric
	CIG	NUMBER OF CIGARETTES SMOKED IN LAST 12 HOURS	Numeric
	HR_LCIG	TIME LAST CIGARETTE (USE 24 HR CLOCK))	time
	SICK	SICK IN THE LAST WEEK 0=NO 1=YES	Numeric
	SURG	ANY RECENT SURGERY INCLUDING DENTAL 0=NO 1=YES	Numeric
	EAR	EAR INFECTION SINCE LAST VISIT 0=NO 1=YES	Numeric
	MED	CURRENTLY TAKING ANY MEDICATION LAST 24 HRS 0=NO 1=YES	Numeric
	INJ	INJURIES TO HEAD NECK OR BACK SINCE LAST VISIT 0=NO 1=YES	Numeric
	F_S	FALLEN/SLIPPED ON THE JOB SINCE LAST VISIT 0=NO 1=YES	Numeric
	ACT	STRENOUS ACTIVITY IN THE LAST 24HRS 0=NO 1=YES	Numeric
	STR	STRESSFUL EVENT AT THE HOME OR JOB IN LAST 24 HRS 0=NO 1=YES	Numeric
	ALC_DRG	ALCOHOL/DRUG CONSUMPTION IN LAST 24HRS	Numeric
	PREG	PREGNANT (PM-POST MENOPAUSE, NA-NOT APPLICABLE) 0=NO 1=YES (NO INCLUDI	Numeric
	TEMP	ORAL TEMPERATURE (F)	Numeric
C	BP	BLOOD PRESSURE	Numeric
	W	WEIGHT (KGS)	kgs
C	POST_DIS	POST TESTING DISCOMFORT RATING 0=NO 1=YES IF YES (WEIGH ON A SCALE OF 0-	Numeric
	Post_1	**NECK** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Post_2	**UPPER BACK** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Post_3	**LEFT SHOULDER** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Post_4	**RIGHT SHOULDER** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Post_5	**LEFT UPPER ARM** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Post_6	**RIGHT UPPER ARM** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Post_7	**BUTTOCKS** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Post_8	**MID TO LOWER BACK** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Post_9	**LEFT FOREARM** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Post_10	**RIGHT FOREARM** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Post_11	**LEFT WRIST** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Post_12	**RIGHT WRIST** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Post_13	**LEFT HAND** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
	Post_14	**RIGHT HAND** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric

0-4

MINING DATA DICTIONARY FOR VARIABLES AND COVARIATES USED IN STATISTICAL MODELS

M =MAIN
O =OUTCOME VARIABLE
C =COVARIATE

		Post_15	**HIPS/WAIST** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
		Post_16	**LEFT THIGH** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
		Post_17	**RIGHT THIGH** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
		Post_18	**KNEES** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
		Post_19	**RIGHT LOWER LEG/FOOT** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3	Numeric
		Post_20	**LEFT LOWER LEG/FOOT** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
		Post_21	**ANKLES** POST TESTING DISCOMFORT (WEIGH ON A SCALE OF 0-3)	Numeric
STRENGTH 1		ID	Subject ID	alpha numeric
		CODE	Test code (0=resting, 1=at least 2 hrs after work or testing session)	numeric
		DATE	Date that strength testing was performed	date
		HAND	Handedness (Right or Left)	alpha
	C	RQ1	Maximal static right quad strength 1	pounds
	C	RQ2	Maximal static right quad strength 2	pounds
	C	RQ3	Maximal static right quad strength 3	pounds
	C	LQ1	Maximal static left quad strength 1	pounds
	C	LQ2	Maximal static left quad strength 2	pounds
	C	LQ3	Maximal static left quad strength 3	pounds
	C	RH1	Maximal static right ham strength 1	pounds
	C	RH2	Maximal static right ham strength 2	pounds
	C	RH3	Maximal static right ham strength 3	pounds
	C	LH1	Maximal static left ham strength 1	pounds
	C	LH2	Maximal static left ham strength 2	pounds
	C	LH3	Maximal static left ham strength 3	pounds
	C	RD1	Maximal static right dorsi strength 1	pounds
	C	RD2	Maximal static right dorsi strength 2	pounds
	C	RD3	Maximal static right dorsi strength 3	pounds
	C	LD1	Maximal static left dorsi strength 1	pounds
	C	LD2	Maximal static left dorsi strength 2	pounds
	C	LD3	Maximal static left dorsi strength 3	pounds
	C	RP1	Maximal static right plantar strength 1	pounds
	C	RP2	Maximal static right plantar strength 2	pounds
	C	RP3	Maximal static right plantar strength 3	pounds
	C	LP1	Maximal static left plantar strength 1	pounds
	C	LP2	Maximal static left plantar strength 2	pounds
	C	LP3	Maximal static left plantar strength 3	pounds

MINING DATA DICTIONARY FOR VARIABLES AND COVARIATES USED IN STATISTICAL MODELS

M =MAIN
O =OUTCOME VARIABLE
C =COVARIATE

load-f		ID	Subject ID	alpha numeric
		FILENAME	Name of the file	alpha numeric
		LOAD_1	First loadcell reading hand recorded from the field	numeric
		LOAD_2	Second loadcell reading hand recorded from the field	numeric
	C	AVG	Average of the first and second loadcell readings from the field	numeric

0-6

MINING DATA DICTIONARY FOR VARIABLES AND COVARIATES USED IN STATISTICAL MODELS

M =MAIN
O =OUTCOME VARIABLE
C =COVARIATE
F =FREQUENCY COUNT

	COLUMN NAME	DESCRIPTION	UNITS
	ID	subject identification	alpha numeric
	DATE	Date that Questionnaire was completed	date
C	MO_WORKED	How long were you/have you been a coal miner? (months)	Numeric
C	MINE_TYPE	Was the last mine you worked at? 1=low seam, 2=high, 3=above ground/strip 12=low and high, 13=low and strip, 23=high and strip, 123=low, high and strip	Numeric
F	EXP_JOB	Exposure to the following jobs 0-None 1-Solvents 2-Lead 3-Tolune 4-Styrene 5-Arsenic 6-Kerosene/Mineral Spirits 7-Perchloroethylene 8-Trichloroethylene 9-Acrylamide 10-Pesticides 11-Combination	Numeric
F	JOB_EVE	=Did you ever had a following job more than a year? 0-None 1-Rubber tire 2-Chemical/paint manufacture 3-Petroleum refining 4-Smelting 5-Commercial painting 6-Foundry 7-Dry cleaning 8-Battery/Lead storage 9-Printing 10-Lead industry 11-Sand blasting	Numeric

prelim quest 1

		12-Combination of above	
F	HOBBIES	0-None	Numeric
		1-Stained glass work	
		2-Mimeography	
		3-House painting	
		4-Melting metal for any purpose	
		5-Model plane/car/building	
		6-Jewelry making	
		7-Paint removal	
		8-Silk screening	
		9-Furniture finishing	
		10-Pottery/ceramic	
		11-Making bullets	
		12-Indoor firing range	
		13-Cutting wood with chain saw	
		14-Combination of above.	
F	MEDS	Are you currently taking any prescription medication? (1=yes, 0=no)	Numeric
C	ALC_DNK	=How often do/did you drink some kind of alcoholic beverages?	numeric
		1-Almost everyday (24)	
		2-Three or four times a week (14)	
		3-Once or twice a week (6)	
		4-Once or twice a month (1.5)	
		5-Less than once a month (0.5)	
C	ALC_AMT	=Amount of alcohol consumed at each sitting (enter number of drinks)	numeric
C	CAF_DNK	=How many caffinated drinks per day you consume?	numeric
C	CIGARET	=How many cigarettes you smoke per day?	numeric
		Medical History	
F	1	Problem with vision	numeric
F	2	Shortness of breath with excersise	numeric
F	3	Weakness in legs	numeric
F	4	Numbness in legs	numeric
F	5	Seizures, fits or convulsions	numeric
F	6	Stroke	numeric
F	7	Sudden blackouts	numeric
F	8	Chronic or recurring spinning dizziness(Vertigo)	numeric
F	9	Chronic or recurring light-heartedness(sensation of fainting)	numeric

* for items 1 through 35

#_P	In the past
#_C	Current
#_LE	Last Episode (Month/Year)

F	10	Meniere's disease	numeric
F	11	Problems with maintaining balance	numeric
F	12	Parkinson's disease	numeric
F	13	Multiple sclerosis	numeric
F	14	Intermittent claudication(poor circulation in legs)	numeric
F	15	Anemia	numeric
F	16	Chronic lung disease(emphysema or bronchitis, or asthma with exercise)	numeric
F	17	Heart disease	numeric
F	18	Abnormal heart rhythm	numeric
F	19	Heart attack	numeric
F	20	Angina	numeric
F	21	Congestive heart failure	numeric
F	22	High blood pressure(hypertension)	numeric
F	23	Chest pain	numeric
F	24	Alcoholism or alcohol abuse	numeric
F	25	Drug addiction or abuse	numeric
F	26	Chronic foot or leg disability	numeric
F	27	Diabetes mellitus(sugar diabetes)	numeric
		Arthritis or pain involving following	
F	28	Neck	numeric
F	29	Lower back	numeric
F	30	Hips	numeric
F	31	Knees	numeric
F	32	Ankles	numeric
F	33	Require use of cane or other walking aid	numeric
F	34	Head,Neck or back injury/surgery	numeric
F	35	Cancer requiring chemotherapy	numeric
	FALL_EVE	= Have you ever had a fall for which there was no clear or identifiable reason?	numeric
	NO_TIM	=How many times in the past year this ever occurred?	numeric
	APX_TIM	=Approximately how many times has this ever occurred?	numeric
	ST_HLTH	=How would you describe your state of health?	numeric
		1-Excellent	
		2-Good	
		3-Fair	
		4-Poor	
	EAR_INF	= Have you had an ear infection within the last month?	numeric
	EAR_PRB	=Do you any ear problems?	numeric

	REG_EXC	=Are you involved in any regular exercise program?	numeric
F	TYP_EXC	=Type of exercise	numeric
		0-None	
		1-Walking	
		2-Jogging	
		3-Bicycling	
		4-Swimming	
		5-Weight lifting	
		6-Racket sports	
		7-Specify	
	NO_HRS	Number of hours per week that you partcipate.	numeric

MINING DATA DICTIONARY FOR VARIABLES AND COVARIATES USED IN STATISTICAL MODELS

M =MAIN
O =OUTCOME VARIABLE
C =COVARIATE

PSOS1

	COLUMN NAME	DESCRIPTION	UNITS
	ID	subject identification	alpha numeric
	DATE	Day of Visit	date
	SESSION	session number	numeric
	FILENAME	Name of the file	alpha numeric
	PSOS/F	Rating of Perceived Sense of Slip during a Gait or Balance test	numeric
	PSOS_1	1) How much did feel yourself slip(i.e. loose traction)? 0 to 2 in increments of 0.5(a little, some, a lot)	
	PSOS_2	2) Did you feel at any time that you would slip and fall? 0 to 2 in increments of 0.5(none, a little, a lot)	
	PSOS_3	3) Did you have any difficulty in maintaining balance while performing the task? 0 to 2 in increments of 0.5(none, a little, a lot)	
	PSOS_4	4) What would you say was the overall difficulty of this task? 0 to 2 in increments of 0.5 (very easy, easy, moderate, somewhat hard, hard)	
O	PSOS	Total of PSOS_1 + PSOS_2 + PSOS_3 + PSOS_4	numeric
O	RPE	The rating of perceived exertion scale (BORG 1980) 6 to 20 in increments of 1 6 to 7 Very very light 8 to 11 Fairly light 12 to 13 Somewhat hard 14 to 17 Very hard 18 to 20 Very very hard	numeric
O	SLIP	0=NO 1=YES	numeric
O	FALL	0=NO 1=YES	numeric

0-11

MINING DATA DICTIONARY FOR VARIABLES AND COVARIATES USED IN STATISTICAL MODELS

M =MAIN
O =OUTCOME VARIABLE
C =COVARIATE

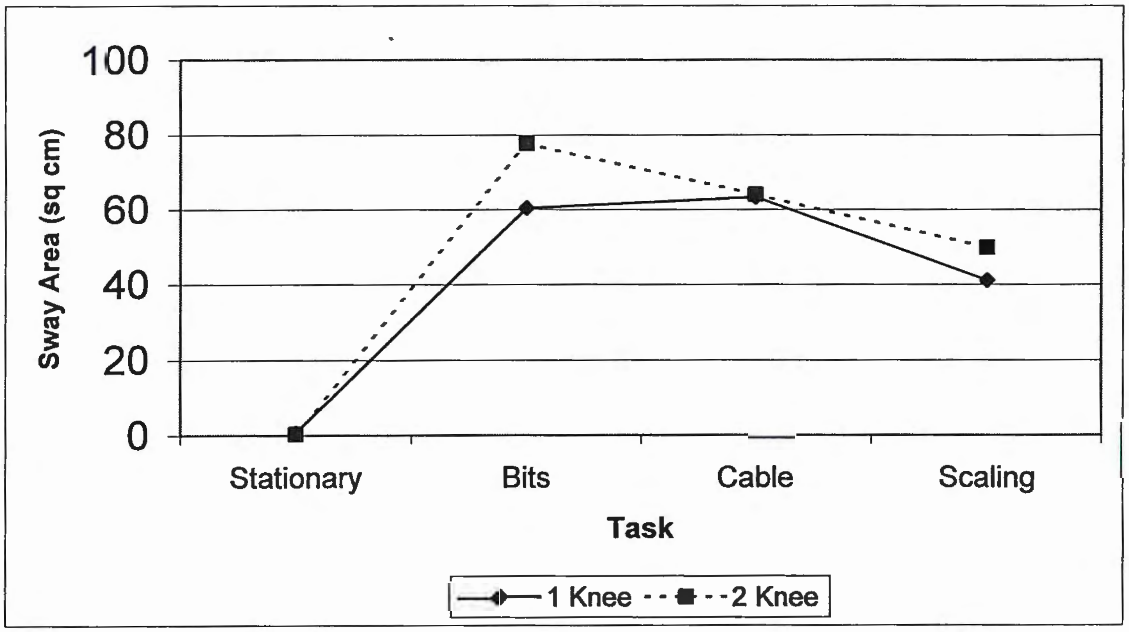
LM-GAIT1	ID	subject identification	alpha numeric
	DATE	Day of Visit	date
	LOC	Location of testing (M=Middlesboro/Field, C=Cincinnati/Lab)	alpha
	TYPE	Type of testing (B=balance, G=gait)	alpha
	SESSION	session number	numeric
	G1G	GAIT TESTING STEP-1(BEFORE PLATE) GOOD LIGHT	footcandles
	G1P	GAIT TESTING STEP-1(BEFORE PLATE)POOR LIGHT	footcandles
	G2G	GAIT TESTING STEP-2(BEFORE PLATE) GOOD LIGHT	footcandles
	G2P	GAIT TESTING STEP-2(BEFORE PLATE) POOR LIGHT	footcandles
	G3G	GAIT TESTING STEP-3 (ON PLATE) GOOD LIGHT	footcandles
	G3P	GAIT TESTING STEP-3 (ON PLATE) POOR LIGHT	footcandles
	G4G	GAIT TESTING STEP-4 (AFTER PLATE) GOOD LIGHT	footcandles
	G4P	GAIT TESTING STEP-4 (AFTER PLATE) POOR LIGHT	footcandles
	G5G	GAIT TESTING STEP-5 (AFTER PLATE) GOOD LIGHT	footcandles
	G5P	GAIT TESTING STEP-5 (AFTER PLATE) POOR LIGHT	footcandles
LM-BAL1	ID	subject identificaiton	alpha numeric
	DATE	Day of Visit	date
	LOC	Location of testing (M=Middlesboro/Field, C=Cincinnati/Lab)	alpha
	TYPE	Type of testing (B=balance, G=gait)	alpha
	SESSION	session number	numeric
	BFG	BALANCE TESTING WITH SENSOR ON FOREHEAD IN GOOD LIGHT	footcandles
	BFP	BALANCE TESTING WITH SENSOR ON FOREHEAD IN POOR LIGHT	footcandles
	BRG	BALANCE TESTING WITH SENSOR ON RIGHT CHEEK IN GOOD LIGHT	footcandles
	BRP	BALANCE TESTING WITH SENSOR ON RIGHT CHEEK IN POOR LIGHT	footcandles
	BLG	BALANCE TESTING WITH SENSOR ON LEFT CHEEK IN GOOD LIGHT	footcandles
	BLP	BALANCE TESTING WITH SENSOR ON LEFT CHEEK IN POOR LIGHT	footcandles
	BAG	BALANCE TESTING AMBIENT IN GOOD LIGHT	footcandles
	BAP	BALANCE TESTING AMBIENT IN POOR LIGHT	footcandles
VISION 1	ID	Subject ID	alpha numeric
	DATE	Date of vision testing	date
	SNELLN	Snellen Equivalent	numeric
	CON	Do you wear contact lenses? (0=no, 1=yes)	numeric
	BIFOC	Do you wear bifocals? (0=no, 1=yes)	numeric
	TRIFOC	Do you wear trifocals? (0=no, 1=yes)	numeric
	LST_EXAM	Last eye exam by doctor?	date
	RX_CHANGE	Did your perscription change? (0=no, 1=yes)	numeric
	DOM_EYE	Dominant eye? (R=right, L=left)	alpha

APPENDIX P

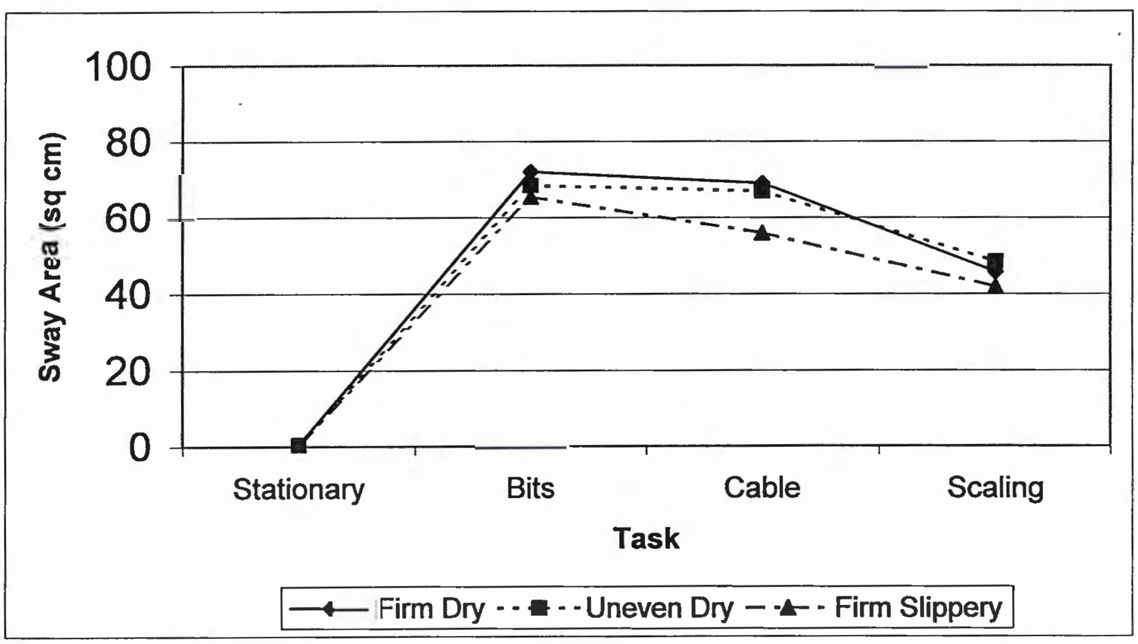
Postural sway and required COF (H/V) outcomes

Table P-1. Geometric Means of Significant Static Postural Balance Sway Area Variables for Lab and Field Data.

SWAY AREA	Category		Geometric Mean	Geometric Standard Error
Task	Bits		68.52	1.06
	Cable		63.63	1.06
	Scaling		45.28	1.06
	Stationary		0.50	1.06
Posture	1 Knee		18.50	1.05
	2 Knee		16.94	1.05
Regular Exercise	No		15.00	1.06
	Yes		20.89	1.08
task*posture	bits	1 knee	60.39	1.07
task*posture	Bits	2 knee	77.74	1.07
task*posture	Cable	1 knee	63.28	1.07
task*posture	Cable	2 knee	63.99	1.07
task*posture	Scaling	1 knee	41.16	1.07
task*posture	Scaling	2 knee	49.82	1.07
task*posture	Stationary	1 knee	0.74	1.07
task*posture	Stationary	2 knee	0.33	1.07
task*surface	Bits	Firm Dry	72.00	1.08
task*surface	Bits	Uneven Dry	68.36	1.07
task*surface	Bits	Firm Slippery	65.36	1.07
task*surface	Cable	Firm Dry	68.94	1.08
task*surface	Cable	Uneven Dry	66.88	1.08
task*surface	Cable	Firm Slippery	55.89	1.08
task*surface	Scaling	Firm Dry	45.76	1.07
task*surface	Scaling	Uneven Dry	48.45	1.07
task*surface	Scaling	Firm Slippery	41.88	1.08
task*surface	Stationary	Firm Dry	0.46	1.07
task*surface	Stationary	Uneven Dry	0.46	1.07
task*surface	Stationary	Firm Slippery	0.57	1.08



a. Interaction of Task and Posture for Sway Area (Lab and Field).

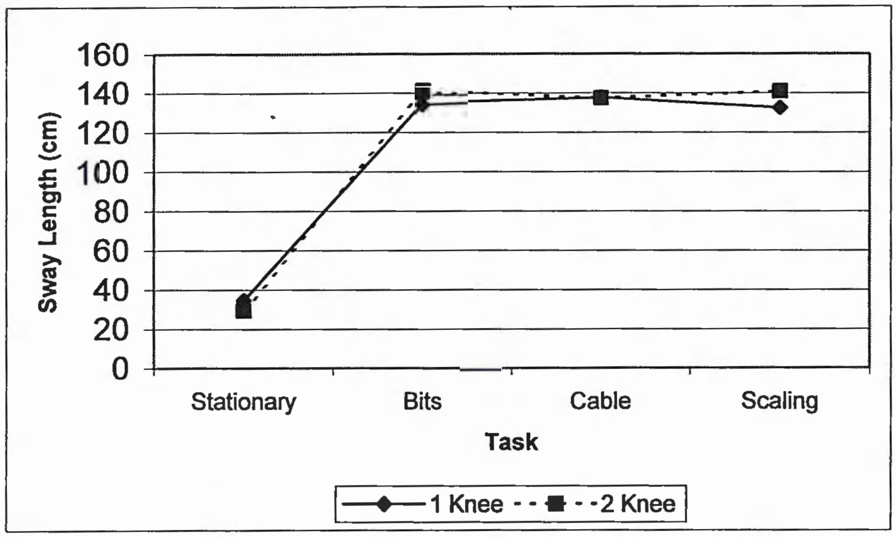


b. Interaction of Task and Surface for Sway Area (Lab and Field).

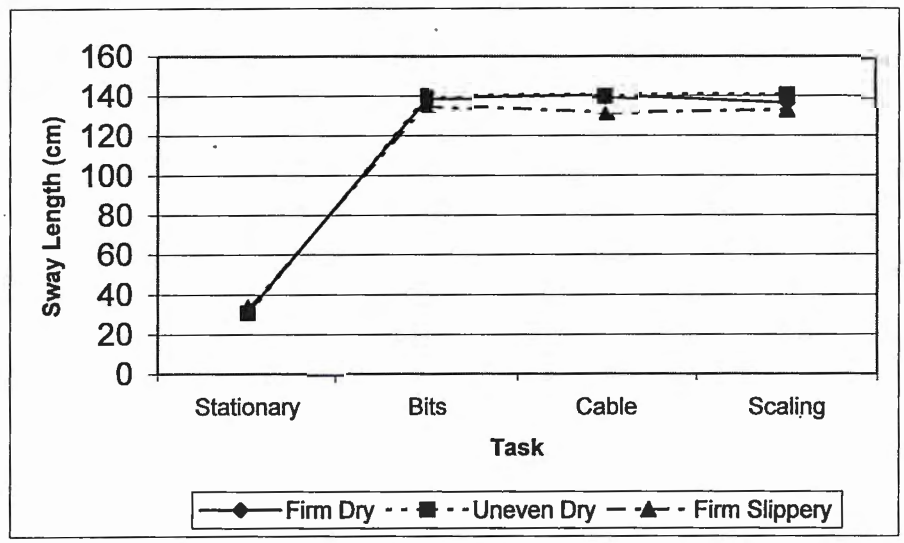
Figure P-1. Significant Interactions for Sway Area (Lab and Field).

Table P-2. Geometric Means of Significant Static Postural Balance Sway Length Variables for Lab and Field Data.

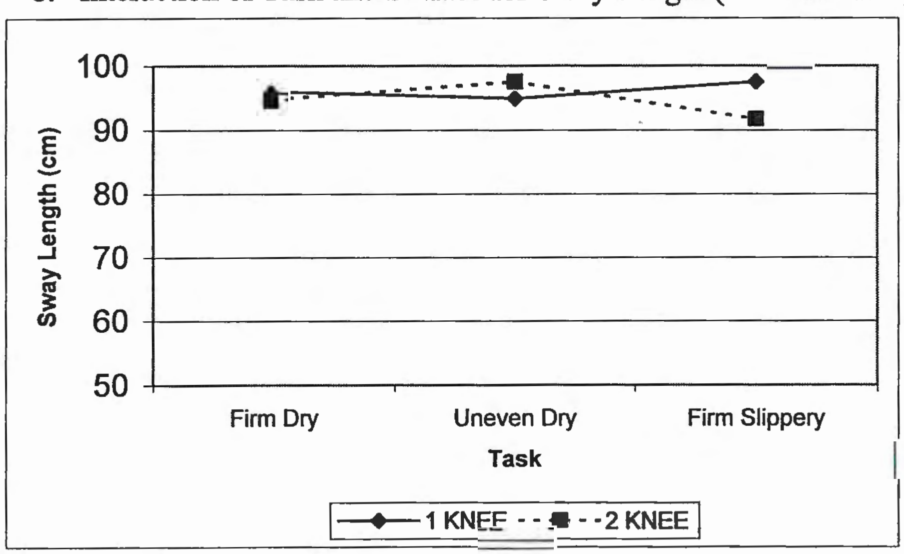
Sway Length	Category		Geometric Mean	Geometric Standard Error
Task	Bits		138.29	1.04
	Cable		137.57	1.04
	Scaling		136.58	1.04
	Stationary		31.91	1.04
Lighting	Poor		93.70	1.03
	Glare		97.17	1.03
Type of Mine	Low Seam		89.80	1.07
	High Seam		90.00	1.07
	Above Ground/Strip		80.15	1.07
	Both Low and High Seam		97.66	1.05
	All (Low, High, Above/Strip)		125.05	1.11
task*posture	bits	1 knee	135.23	1.04
task*posture	bits	2 knee	141.43	1.04
task*posture	cable	1 knee	137.73	1.04
task*posture	cable	2 knee	137.40	1.04
task*posture	scaling	1 knee	132.47	1.04
task*posture	scaling	2 knee	140.82	1.04
task*posture	stationary	1 knee	34.67	1.04
task*posture	stationary	2 knee	29.36	1.04
task*surface	bits	Firm Dry	139.19	1.04
task*surface	bits	Uneven Dry	140.06	1.04
task*surface	bits	Firm Slippery	135.67	1.04
task*surface	cable	Firm Dry	140.48	1.04
task*surface	cable	Uneven Dry	140.87	1.04
task*surface	cable	Firm Slippery	131.55	1.04
task*surface	scaling	Firm Dry	136.35	1.04
task*surface	scaling	Uneven Dry	140.65	1.04
task*surface	scaling	Firm Slippery	132.85	1.04
task*surface	stationary	Firm Dry	31.11	1.04
task*surface	stationary	Uneven Dry	30.90	1.04
task*surface	stationary	Firm Slippery	33.78	1.04
posture*surface	Firm Dry	1 knee	96.04	1.04
posture*surface	Uneven Dry	1knee	94.94	1.04
posture*surface	Firm Slippery	1 knee	97.55	1.04
posture*surface	Firm Dry	2 knee	94.83	1.04
posture*surface	Uneven Dry	2 knee	97.54	1.04
posture*surface	Firm Slippery	2 knee	91.74	1.04



a. Interaction of Task and Posture for Sway Length (Lab and Field).



b. Interaction of Task and Surface for Sway Length (Lab and Field).

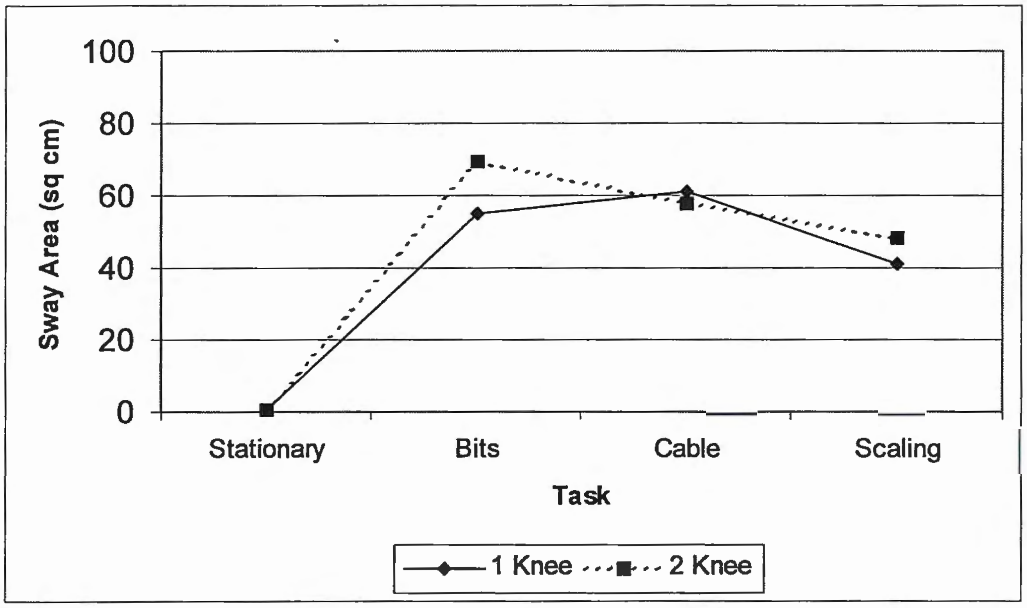


c. Interaction of Task and Posture for Sway Length (Lab and Field).

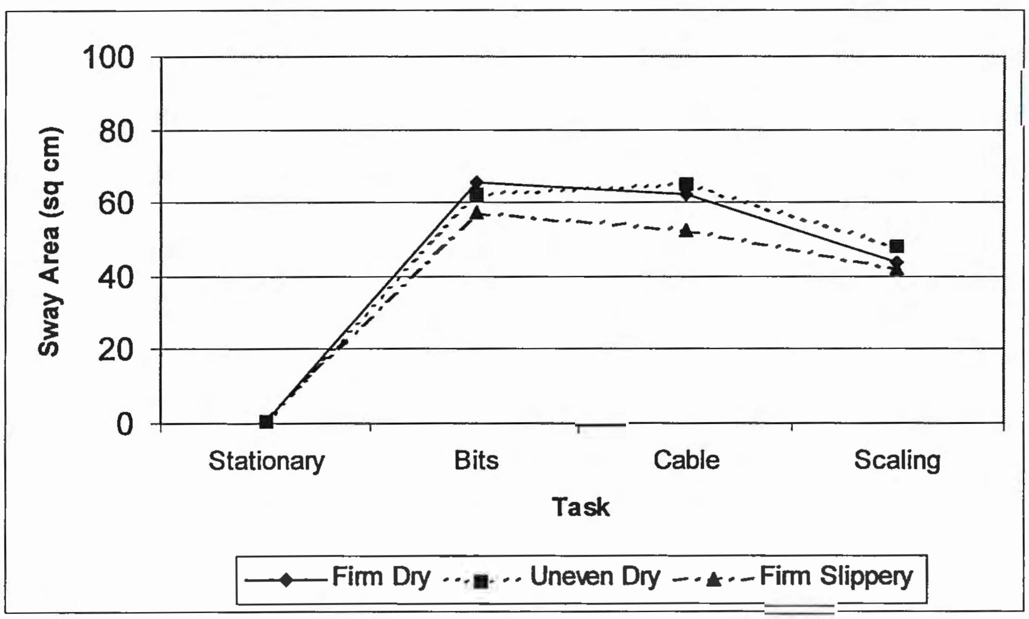
Figure P-2. Significant Interactions for Sway Length (Lab and Field).

Table P-3. Geometric Means of Significant Static Postural Balance Sway Area Variables for Lab Data Only.

Sway Area	Category		Geometric Mean	Geometric Standard Error
task	bits		61.63	1.07
	cable		59.53	1.08
	scaling		44.46	1.07
	stationary		0.44	1.07
posture	1 knee		17.10	1.07
	2 knee		15.66	1.07
task*posture	bits	1 knee	54.74	1.08
task*posture	bits	2 knee	69.39	1.08
task*posture	cable	1 knee	61.05	1.08
task*posture	cable	2 knee	58.04	1.10
task*posture	scaling	1 knee	41.12	1.08
task*posture	scaling	2 knee	48.08	1.08
task*posture	stationary	1 knee	0.62	1.08
task*posture	stationary	2 knee	0.31	1.08
task*surface	bits	Firm Dry	65.74	1.09
task*surface	bits	Uneven Dry	62.32	1.09
task*surface	bits	Firm Slippery	57.14	1.09
task*surface	cable	Firm Dry	62.24	1.10
task*surface	cable	Uneven Dry	64.89	1.10
task*surface	cable	Firm Slippery	52.23	1.10
task*surface	scaling	Firm Dry	43.84	1.09
task*surface	scaling	Uneven Dry	47.83	1.09
task*surface	scaling	Firm Slippery	41.92	1.09
task*surface	stationary	Firm Dry	0.41	1.09
task*surface	stationary	Uneven Dry	0.41	1.09
task*surface	stationary	Firm Slippery	0.50	1.09



a. Interaction of Task and Posture for Sway Area (Lab only).

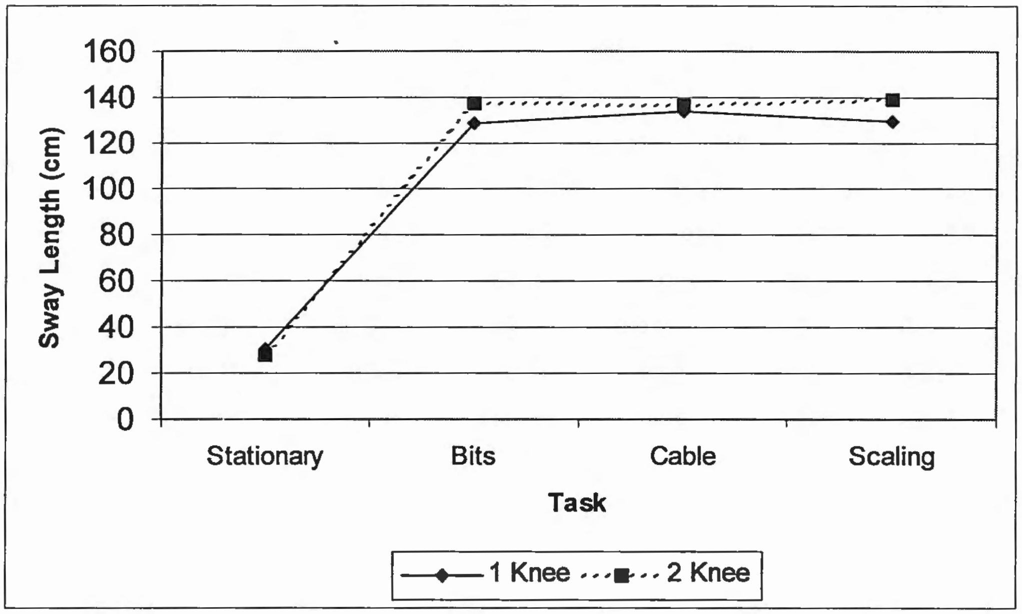


b. Interaction of Task and Surface for Sway Area (Lab only).

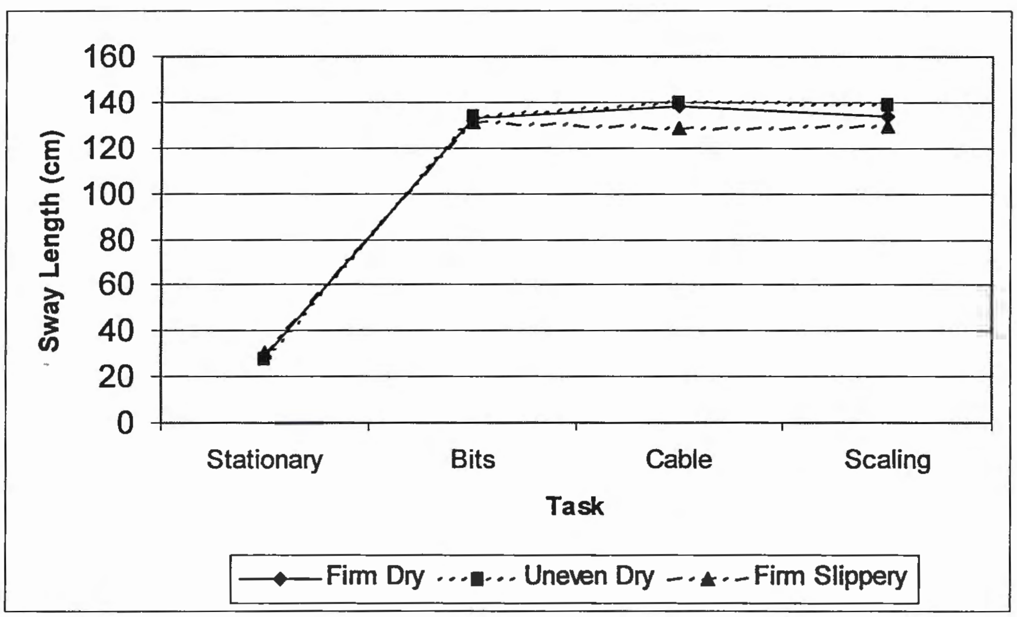
Figure P-3. Significant Interactions for Sway Area (Lab only).

Table P-4. Geometric Means of Significant Static Postural Balance Sway Length Variables for Lab Data Only.

Sway Length	Category		Geometric Mean	Geometric Standard Error
TASK	BITS		132.69	1.04
	CABLE		135.26	1.04
	SCALING		134.04	1.04
	STATIONARY		29.39	1.04
LIGHTING	POOR		90.21	1.04
	GLARE		93.21	1.04
task*posture	bits	1 knee	128.50	1.04
task*posture	bits	2 knee	137.01	1.04
task*posture	cable	1 knee	134.13	1.04
task*posture	cable	2 knee	136.40	1.05
task*posture	scaling	1 knee	129.42	1.04
task*posture	scaling	2 knee	138.82	1.04
task*posture	stationary	1 knee	30.61	1.04
task*posture	stationary	2 knee	28.21	1.04
task*surface	bits	Firm Dry	133.01	1.05
task*surface	bits	Uneven Dry	134.00	1.05
task*surface	bits	Firm Slippery	131.07	1.05
task*surface	cable	Firm Dry	137.81	1.05
task*surface	cable	Uneven Dry	140.08	1.05
task*surface	cable	Firm Slippery	128.20	1.05
task*surface	scaling	Firm Dry	133.67	1.05
task*surface	scaling	Uneven Dry	139.07	1.05
task*surface	scaling	Firm Slippery	129.55	1.05
task*surface	stationary	Firm Dry	29.01	1.05
task*surface	stationary	Uneven Dry	28.21	1.05
task*surface	stationary	Firm Slippery	31.01	1.05



a. Interaction between Task and Posture for Sway Length (Lab only)



b. Interaction between Task and Surface for Sway Length (Lab only).

Figure P-4. Significant Interactions for Sway Length (Lab only).

Table P-5. Geometric Means of Significant Static Postural Balance Excursion X (ML) Variables for Lab Data Only.

Excursion X (ML)	Category		Mean	Standard Error
Task	bits		18.25	0.39
	cable		7.90	0.41
	scaling		9.56	0.40
	stationary		0.76	0.40
Posture	1 knee		8.46	0.36
	2 knee		9.77	0.37
Type of Mine	Low Seam		11.13	0.64
	High Seam		8.27	0.53
	Above Ground/Strip		7.85	0.95
	Both Low and High Seam		9.58	0.40
	All (Low, High, Above/Strip)		8.75	1.10
task*posture	bits	1 knee	15.08	0.46
task*posture	bits	2 knee	21.42	0.45
task*posture	cable	1 knee	8.58	0.44
task*posture	cable	2 knee	7.22	0.52
task*posture	scaling	1 knee	9.07	0.46
task*posture	scaling	2 knee	10.05	0.45
task*posture	stationary	1 knee	1.14	0.46
task*posture	stationary	2 knee	0.39	0.45

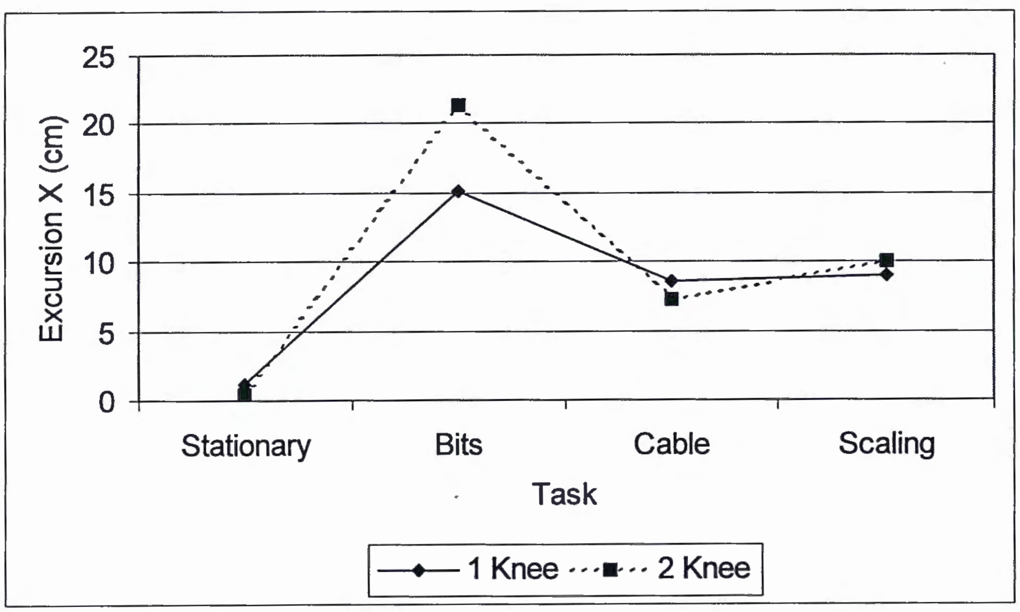
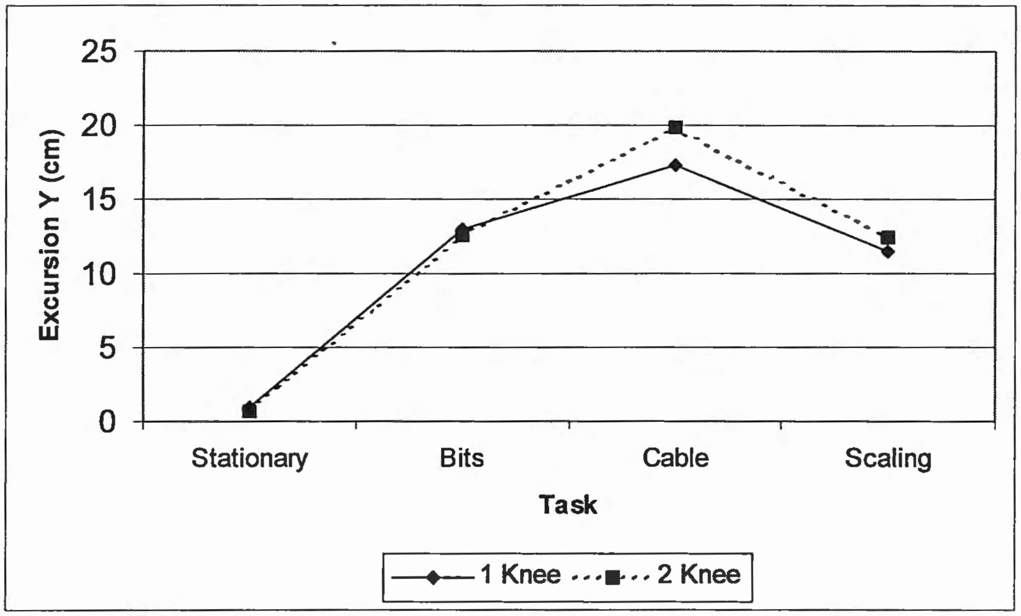


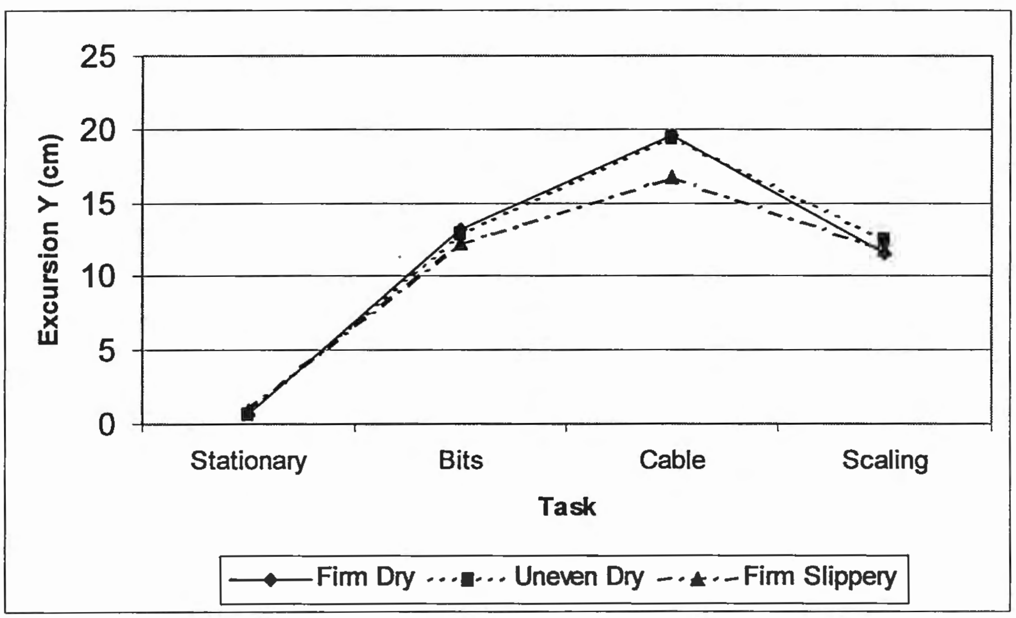
Figure P-5. Significant Interaction for Excursion X [ML] (Lab only).

Table P-6. Geometric Means of Significant Static Postural Balance Excursion Y (AP) Variables for Lab Data Only.

Excursion Y (AP)	Category		Mean	Standard Error
task	bits		12.75	0.53
	cable		18.60	0.55
	scaling		11.96	0.53
	stationary		0.79	0.53
posture	1 knee		10.67	0.49
	2 knee		11.38	0.50
surface	Firm Dry		11.26	0.52
	Uneven Dry		11.41	0.51
	Firm Slippery		10.41	0.52
task*posture	bits	1KNEE	12.99	0.59
task*posture	bits	2KNEE	12.51	0.59
task*posture	cable	1KNEE	17.36	0.58
task*posture	cable	2KNEE	19.84	0.67
task*posture	scaling	1KNEE	11.44	0.59
task*posture	scaling	2KNEE	12.48	0.59
task*posture	stationary	1KNEE	0.89	0.60
task*posture	stationary	2KNEE	0.69	0.60
task*surface	bits	Firm Dry	13.15	0.65
task*surface	bits	Uneven Dry	12.92	0.64
task*surface	bits	Firm Slippery	12.18	0.66
task*surface	cable	Firm Dry	19.63	0.69
task*surface	cable	Uneven Dry	19.49	0.68
task*surface	cable	Firm Slippery	16.68	0.69
task*surface	scaling	Firm Dry	11.56	0.66
task*surface	scaling	Uneven Dry	12.52	0.64
task*surface	scaling	Firm Slippery	11.80	0.65
task*surface	stationary	Firm Dry	0.69	0.65
task*surface	stationary	Uneven Dry	0.71	0.65
task*surface	stationary	Firm Slippery	0.98	0.66



a. Interaction between Task and Posture for Excursion Y [AP] (Lab only).

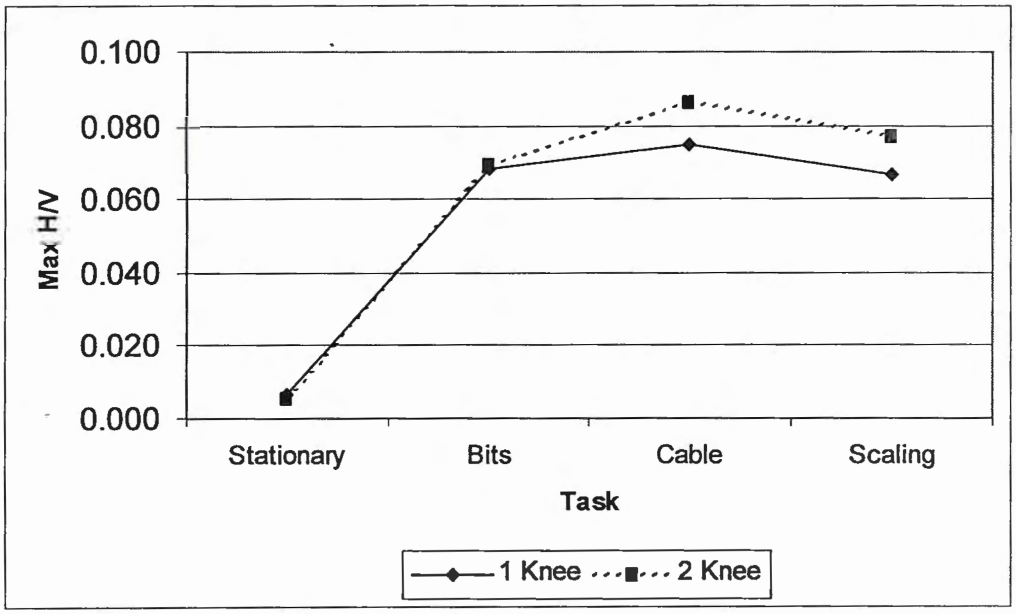


b. Interaction between Task and Surface for Excursion Y [AP] (Lab only).

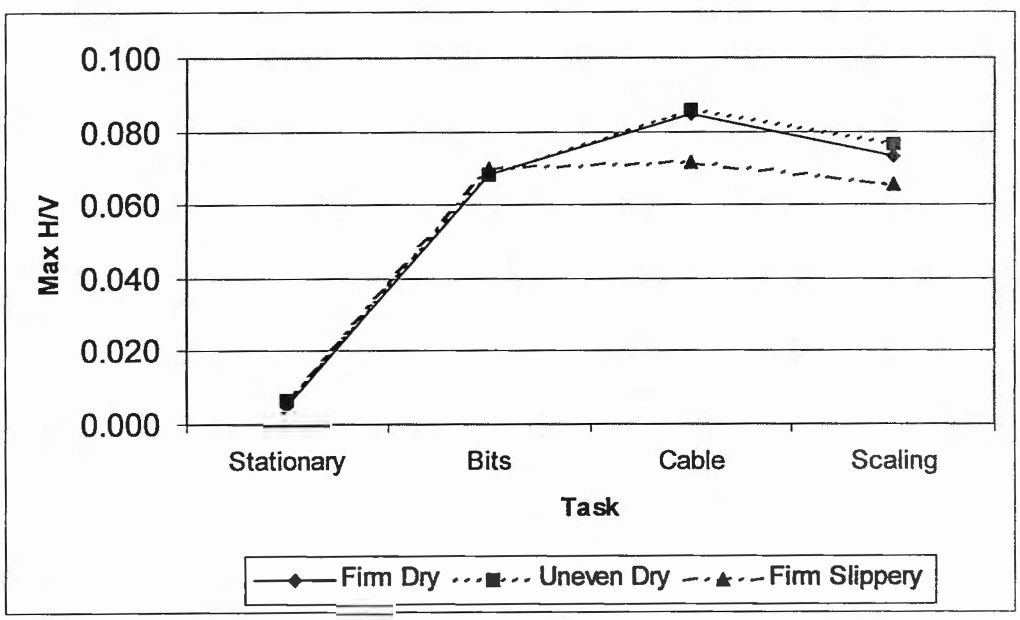
Figure P-6. Significant Interactions for Excursion Y [AP] (Lab only).

Table P-7. Geometric Means of Significant Static Postural Balance Maximum H/V Variables for Lab Data Only.

Maximum H/V	Category		Mean	Standard Error
task	bits		0.069	0.0038
	cable		0.081	0.0039
	scaling		0.072	0.0038
	stationary		0.006	0.0038
posture	1KNEE		0.054	0.0036
	2KNEE		0.060	0.0037
surface	Firm Dry		0.058	0.0037
	Uneven Dry		0.059	0.0037
	Firm Slippery		0.053	0.0037
task*posture	bits	1KNEE	0.0685	0.0041
task*posture	bits	2KNEE	0.0691	0.0041
task*posture	cable	1KNEE	0.0750	0.0040
task*posture	cable	2KNEE	0.0864	0.0045
task*posture	scaling	1KNEE	0.0665	0.0041
task*posture	scaling	2KNEE	0.0771	0.0041
task*posture	stationary	1KNEE	0.0064	0.0041
task*posture	stationary	2KNEE	0.0054	0.0041
task*surface	bits	Firm Dry	0.0684	0.0044
task*surface	bits	Uneven Dry	0.0681	0.0043
task*surface	bits	Firm Slippery	0.0701	0.0044
task*surface	cable	Firm Dry	0.0845	0.0046
task*surface	cable	Uneven Dry	0.0860	0.0045
task*surface	cable	Firm Slippery	0.0716	0.0046
task*surface	scaling	Firm Dry	0.0733	0.0044
task*surface	scaling	Uneven Dry	0.0766	0.0043
task*surface	scaling	Firm Slippery	0.0656	0.0044
task*surface	stationary	Firm Dry	0.0047	0.0044
task*surface	stationary	Uneven Dry	0.0066	0.0044
task*surface	stationary	Firm Slippery	0.0063	0.0044



a. Interaction between Task and Posture for Maximum H/V (Lab only).



b. Interaction between Task and Surface for Maximum H/V (Lab only).

Figure P-7. Significant Interactions for Maximum H/V (Lab only).

APPENDIX Q

CP-based Postural Stability outcomes

Table Q-1. Geometric Means of Significant Static Postural Balance CP-based IPSB-minimum variables for Lab data only.

CP-based IPSB_minimum	Category	Geometric Mean	Geometric Standard Error
task	bits	0.10	1.01
	cable	-0.07	1.01
	scaling	0.12	1.01
	stationary	0.41	1.03
posture	1KNEE	-0.09	1.01
	2KNEE	0.39	1.01

Table Q-2. Geometric Means of Significant Static Postural Balance CP-based WRTI variables for Lab data only.

CP-based WRTI	Category	Geometric Mean	Geometric Standard Error
task	bits	2213.87	1.12
	cable	2836.51	1.12
	scaling	2446.43	1.12
	stationary	1742.28	1.26
posture	1KNEE	5965.94	1.12
	2KNEE	867.19	1.12

Table Q-3. Geometric Means of Significant Static Postural Balance CP-based SAR variables for Lab data only.

CP-based SAR	Category		Geometric Mean	Geometric Standard Error
task	bits		1.88	1.04
	cable		1.06	1.04
	scaling		1.00	1.04
	stationary		0.09	1.06
posture	1KNEE		1.00	1.04
	2KNEE		0.80	1.04
task*posture	bits	1KNEE	2.02	1.04
task*posture	bits	2KNEE	1.75	1.04
task*posture	cable	1KNEE	1.34	1.04
task*posture	cable	2KNEE	0.82	1.04
task*posture	scaling	1KNEE	1.07	1.04
task*posture	scaling	2KNEE	0.93	1.04
task*posture	stationary	1KNEE	0.10	1.08
task*posture	stationary	2KNEE	0.08	1.07

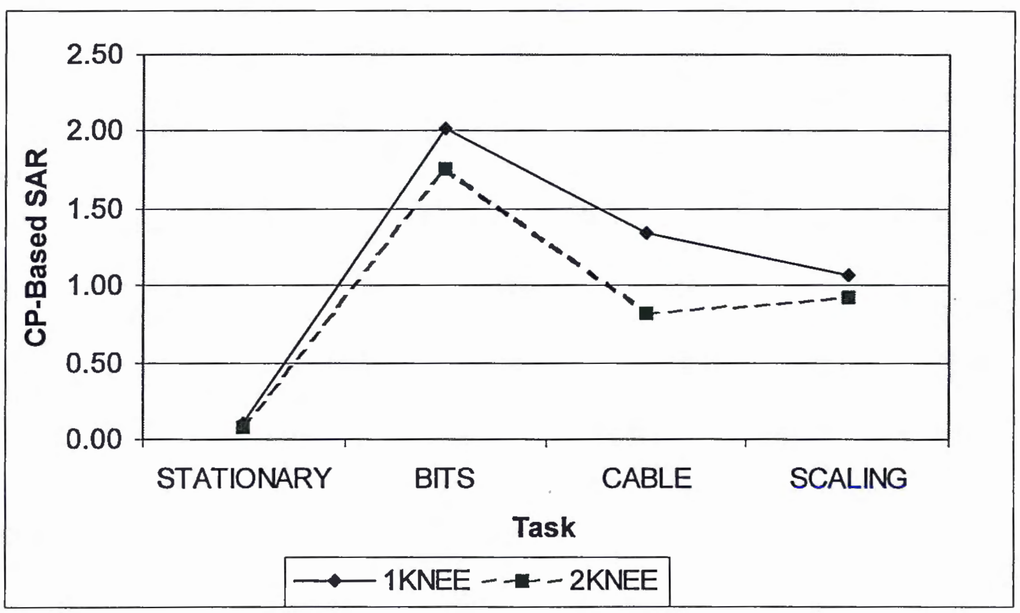


Figure Q-1. Significant Interaction of Task and Posture for CP-based SAR (Lab only).

APPENDIX R

CG-based Postural Stability outcomes

Table R-1. Geometric Means of Significant Static Postural Balance CG-based IPSB-minimum variables for Lab data only.

CG-based IPSB_minimum	Category		Geometric Mean	Geometric Standard Error
task	bits		-0.17	1.02
	cable		-0.54	1.02
	scaling		0.12	1.02
	stationary		0.22	1.02
posture	1KNEE		-0.42	1.02
	2KNEE		0.24	1.02
surface	Firm Dry		-0.07	1.02
	Uneven Dry		-0.10	1.02
	Firm Slippery		-0.15	1.02
Regular Exercise	No		0.02	1.02
	Yes		-0.23	1.03
task*posture	bits	1KNEE	-0.45	1.02
task*posture	bits	2KNEE	0.14	1.02
task*posture	cable	1KNEE	-0.88	1.02
task*posture	cable	2KNEE	-0.14	1.02
task*posture	scaling	1KNEE	-0.16	1.02
task*posture	scaling	2KNEE	0.44	1.02
task*posture	stationary	1KNEE	-0.09	1.02
task*posture	stationary	2KNEE	0.56	1.02

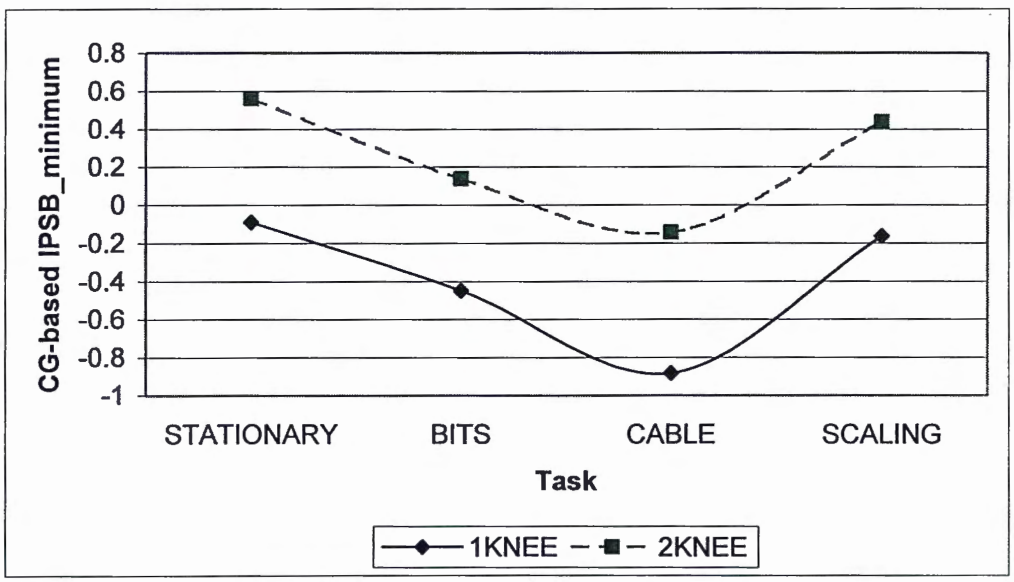


Figure R-1. Significant Interaction of Task and Posture for CG-based IPSB_minimum (Lab only).

Table R-2. Geometric Means of Significant Static Postural Balance CG-based WRTI variables for Lab data only.

CG-based WRTI	Category		Geometric Mean	Geometric Standard Error
task	bits		2867.71	1.13
	cable		2765.50	1.13
	scaling		1748.18	1.13
	stationary		890.66	1.14
posture	1KNEE		2143.93	1.10
	2KNEE		1639.67	1.10
surface	Firm Dry		1435.16	1.11
	Uneven Dry		2282.68	1.11
	Firm Slippery		2011.79	1.12
task*posture	bits	1KNEE	3228.52	1.18
task*posture	bits	2KNEE	2547.18	1.18
task*posture	cable	1KNEE	2005.38	1.18
task*posture	cable	2KNEE	3813.30	1.18
task*posture	scaling	1KNEE	4027.36	1.19
task*posture	scaling	2KNEE	757.89	1.18
task*posture	stationary	1KNEE	809.22	1.19
task*posture	stationary	2KNEE	980.26	1.20

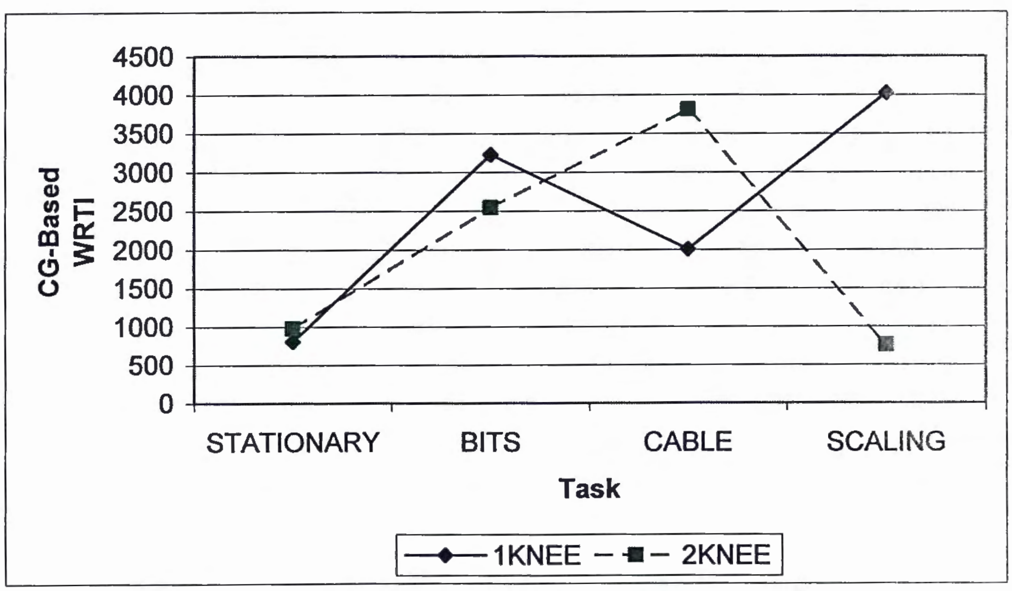


Figure R-2. Significant Interaction of Task and Posture for CG-based WRTI (Lab only).

Table R-3. Geometric Means of Significant Static Postural Balance CG-based SAR variables for Lab data only.

CG-based SAR	Category		Geometric Mean	Geometric Standard Error
task	bits		1.75	1.02
	cable		0.87	1.02
	scaling		0.51	1.02
	stationary		0.03	1.02
posture	1KNEE		0.81	1.02
	2KNEE		0.57	1.02
task*posture	bits	1KNEE	2.06	1.03
task*posture	bits	2KNEE	1.46	1.03
task*posture	cable	1KNEE	1.14	1.03
task*posture	cable	2KNEE	0.64	1.03
task*posture	scaling	1KNEE	0.55	1.03
task*posture	scaling	2KNEE	0.47	1.03
task*posture	stationary	1KNEE	0.05	1.03
task*posture	stationary	2KNEE	0.02	1.03

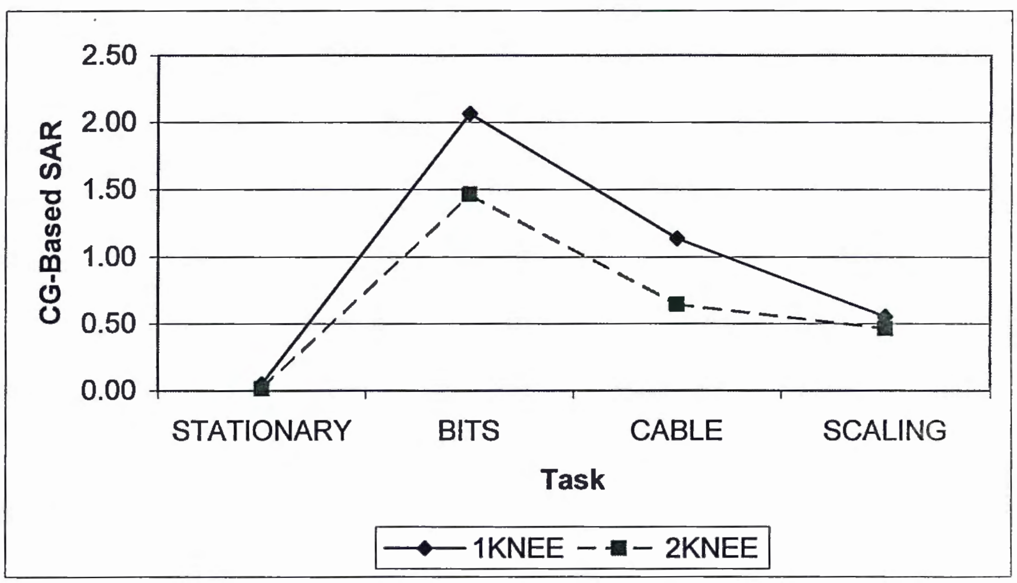


Figure R-3. Significant Interaction of Task and Posture for CP-based SAR (Lab only).

APPENDIX S

Perceived Exertion and PSOF outcomes for Static balance tasks

Table S-1. Least Square Means of Significant Static Postural Balance Perceived Sense of Slip (PSOS) variables.

Balance PSOS	Category	Mean	Standard Error
Task	Bits	1.61	0.20
	Cable	1.56	0.20
	Scaling	1.74	0.20
	Stationary	0.66	0.20
Posture	1 Knee	1.59	0.20
	2 Knee	1.19	0.20
Surface	Firm Dry	1.20	0.20
	Uneven Dry	1.15	0.20
	Firm Slip	1.83	0.20
Lighting	Poor	1.31	0.20
	Glare	1.47	0.20

Table S-2. Least Square Means of Significant Static Postural Balance Rating of Perceived Exertion (RPE) variables.

Balance-RPE	Category		Mean	Standard Error
task	bits		8.48	0.32
	cable		8.52	0.32
	scaling		8.96	0.32
	stationary		6.98	0.32
posture	1KNEE		8.35	0.31
	2KNEE		8.12	0.31
surface	Firm Dry		7.98	0.32
	Uneven Dry		8.35	0.32
	Firm Slip		8.38	0.32
lighting	Poor		8.14	0.31
	Glare		8.33	0.31
task*surface	bits	Firm Dry	8.09	0.35
task*surface	bits	Uneven Dry	8.65	0.35
task*surface	bits	Firm Slippery	8.71	0.35
task*surface	cable	Firm Dry	8.15	0.35
task*surface	cable	Uneven Dry	8.82	0.35
task*surface	cable	Firm Slippery	8.60	0.35
task*surface	scaling	Firm Dry	8.70	0.35
task*surface	scaling	Uneven Dry	9.22	0.35
task*surface	scaling	Firm Slippery	8.97	0.35
task*surface	stationary	Firm Dry	6.98	0.35
task*surface	stationary	Uneven Dry	6.70	0.35
task*surface	stationary	Firm Slippery	7.25	0.35

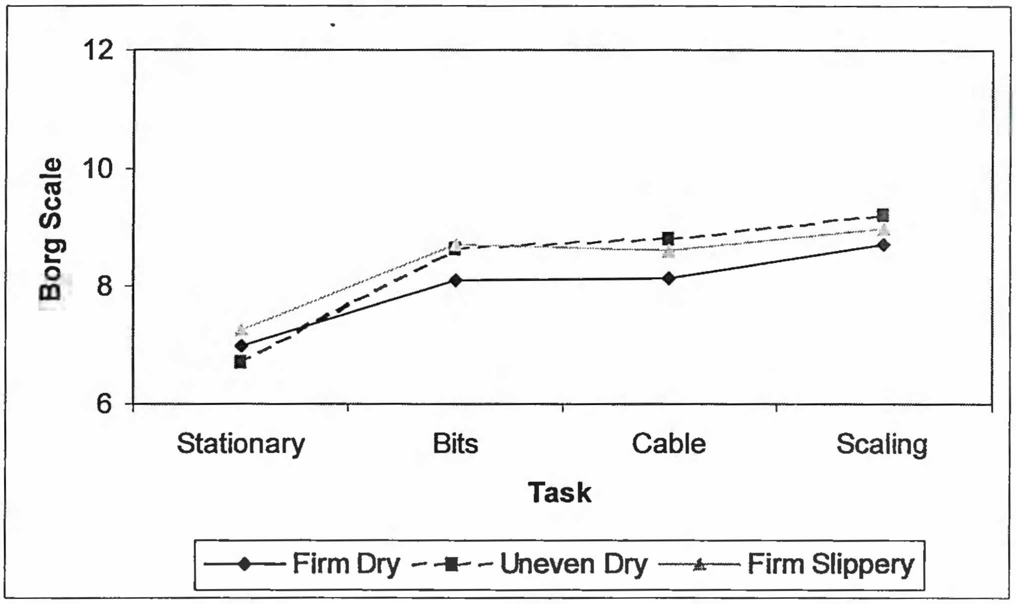


Figure S-1. Significant Interaction of Task and Surface for RPE.

APPENDIX T

Slips and Falls during Static balance tasks

Table T-1. Odds Ratios of Significant Static Postural Balance Observed Slips.

Task1	Task2	Odds Ratio
Bits	Cable	1.00
Bits	Scaling	1.24
Bits	Stationary	7.49
Cable	Scaling	1.24
Cable	Stationary	7.49
Scaling	Stationary	1.42

Posture1	Posture2	Odds Ratio
1 Knee	2 Knee	1.42

Surface1	Surface2	Odds Ratio
Uneven-Dry	Firm-Dry	1.00
Firm-Slip	Firm-Dry	16.70
Firm-Slip	Uneven-Dry	16.70

Lighting1	Lighting2	Odds Ratio
Poor	Glare	1.59

APPENDIX U

Frequency of Slips/Falls for Static Balance and Dynamic Gait

Table U-1. Number of Slips by Weight Carried for Gait Testing

	Weight	No Weight	Total
No Slip	177	202	379
Slip	120	98	218
Total	297	300	597

Table U-2. Number of Falls by Weight Carried for Gait Testing

	Weight	No Weight	Total
No Fall	286	293	579
Fall	11	7	18
Total	297	300	597

Table U-3. Number of Slips by Surface for Gait Testing

	Firm Dry	Uneven Dry	Firm Slip	Total
No Slip	184	162	33	379
Slip	16	36	166	218
Total	200	198	199	597

Table U-4. Number of Falls by Surface for Gait Testing

	Firm Dry	Uneven Dry	Firm Slip	Total
No Fall	199	197	183	579
Fall	1	1	16	18
Total	200	198	199	597

Table U-5. Number of Slips by Lighting for Gait Testing

	Poor Light	Glare Light	Total
No Slip	188	191	379
Slip	112	106	218
Total	300	297	597

Table U-6. Number of Falls by Lighting for Gait Testing

	Poor Light	Glare Light	Total
No Fall	291	288	579
Fall	9	9	18
Total	300	297	597

Table U-7. Number of Slips by Footwear for Gait Testing

	Shoe (Steel toe boot)	Boot (Rubber boot)	Total
No Slip	198	181	379
Slip	101	117	218
Total	299	298	597

Table U-8. Number of Falls by Footwear for Gait Testing

	Shoe (Steel toe boot)	Boot (Rubber boot)	Total
No Fall	296	283	579
Fall	3	15	18
Total	299	298	597

Table U-9. Number of Slips by Task for Balance Testing

	Bits	Cable	Scaling	Stationary	Total
No Slip	241	240	251	288	1020
Slip	58	56	49	12	175
Total	299	296	300	300	1195

Table U-10. Number of Falls by Task for Balance Testing

	Bits	Cable	Scaling	Stationary	Total
No Fall	298	296	300	300	1194
Fall	1	0	0	0	1
Total	299	296	300	300	1195

Table U-11. Number of Slips by Posture for Balance Testing

	1 Knee	2 Knee	Total
No Slip	501	519	1020
Slip	97	78	175
Total	598	597	1195

Table U-12. Number of Falls by Posture for Balance Testing

	1 Knee	2 Knee	Total
No Fall	597	597	1194
Fall	1	0	1
Total	598	597	1195

Table U-13. Number of Slips by Surface for Balance Testing

	Firm Dry	Uneven Dry	Firm Slip	Total
No Slip	384	381	255	1020
Slip	15	15	145	175
Total	399	396	400	1195

Table U-14. Number of Falls by Surface for Balance Testing

	Firm Dry	Uneven Dry	Firm Slip	Total
No Fall	399	396	399	1194
Fall	0	0	1	1
Total	399	396	400	1195

Table U-15. Number of Slips by Lighting for Balance Testing

	Poor Lighting	Glare Lighting	Total
No Slip	497	523	1020
Slip	101	74	175
Total	598	597	1195

Table U-16. Number of Falls by Lighting for Balance Testing

	Poor Lighting	Glare Lighting	Total
No Slip	598	596	1194
Slip	0	1	1
Total	598	597	1195

APPENDIX V

Ground Reaction Forces of Right Foot (GRR) outcomes

Table V-1. Least Square Means of Significant Dynamic Postural Balance GRR – Maximum Medial Force variables.

GRR - Maximum Medial Force	Category		Mean	Standard Error
surface	Firm Dry		113.75	4.96
	Uneven Dry		119.41	5.07
	Firm Slippery		87.78	4.96
surface*footwear	Firm dry	Shoe	112.80	5.25
surface*footwear	Firm dry	Boot	114.69	5.24
surface*footwear	Uneven dry	Shoe	114.67	5.40
surface*footwear	Uneven dry	Boot	124.14	5.43
surface*footwear	Firm slippery	Shoe	93.08	5.26
surface*footwear	Firm slippery	Boot	82.48	5.25

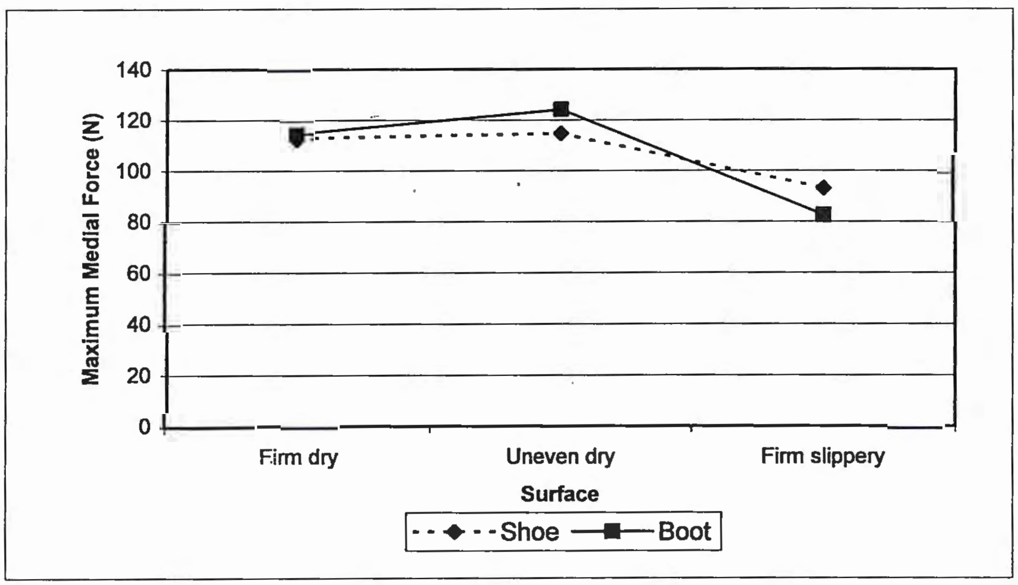


Figure V-1. Significant Interaction of Surface and Footwear for Dynamic Postural Balance GRR – Maximum Medial Force.

Table V-2. Least Square Means of Significant Dynamic Postural Balance GRR – Maximum Braking Force variables.

GRR - Maximum Braking Force	Category		Mean	Standard Error
weight	Yes		-119.08	8.88
	No		-108.43	8.87
surface	Firm dry		-123.96	9.07
	Uneven dry		-144.06	9.17
	Firm slippery		-73.24	9.09
surface*lighting	Firm dry	Poor	-118.73	9.70
surface*lighting	Firm dry	Glare	-129.18	9.71
surface*lighting	Uneven dry	Poor	-152.83	9.84
surface*lighting	Uneven dry	Glare	-135.29	9.88
surface*lighting	Firm slippery	Poor	-71.10	9.72
surface*lighting	Firm slippery	Glare	-75.38	9.73

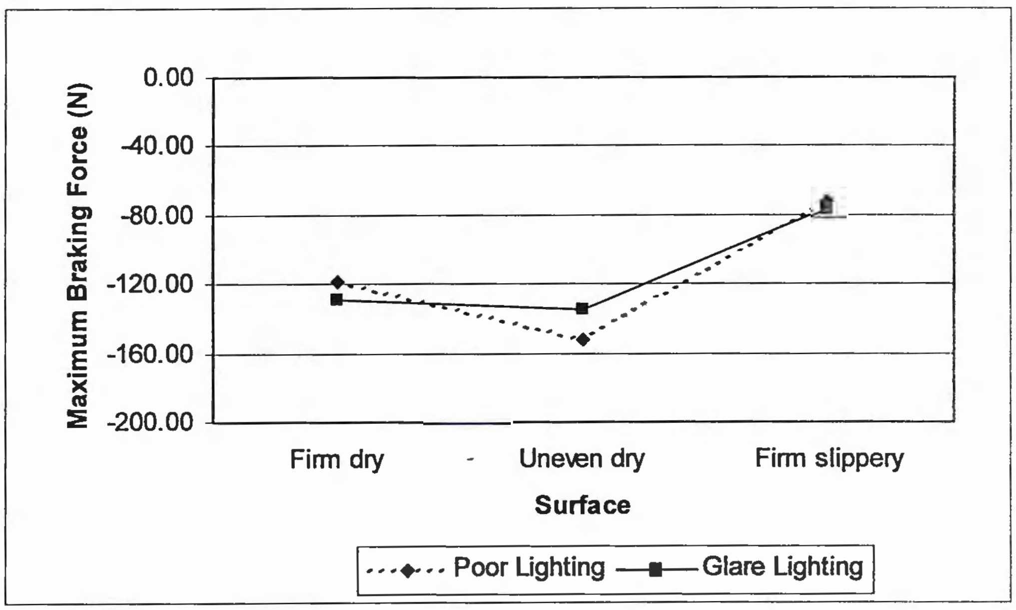


Figure V-2. Significant Interaction for of Surface and Lighting for Dynamic Postural Balance GRR – Maximum Braking Force.

Table V-3. Least Square Means of Significant Dynamic Postural Balance GRR – Maximum Propulsion Force variables.

GRR - Maximum Propulsion Force	Category		Mean	Standard Error
surface	Firm dry		117.92	5.21
	Uneven dry		124.65	5.21
	Firm slippery		77.41	5.21
footwear	Shot		110.25	5.05
	Boot		103.07	5.05
surface*footwear	Firm dry	Shoe	117.63	5.68
surface*footwear	Firm dry	Boot	118.21	5.67
surface*footwear	Uneven dry	Shoe	125.15	5.67
surface*footwear	Uneven dry	Boot	124.15	5.70
surface*footwear	Firm slippery	Shoe	87.95	5.69
surface*footwear	Firm slippery	Boot	66.86	5.68

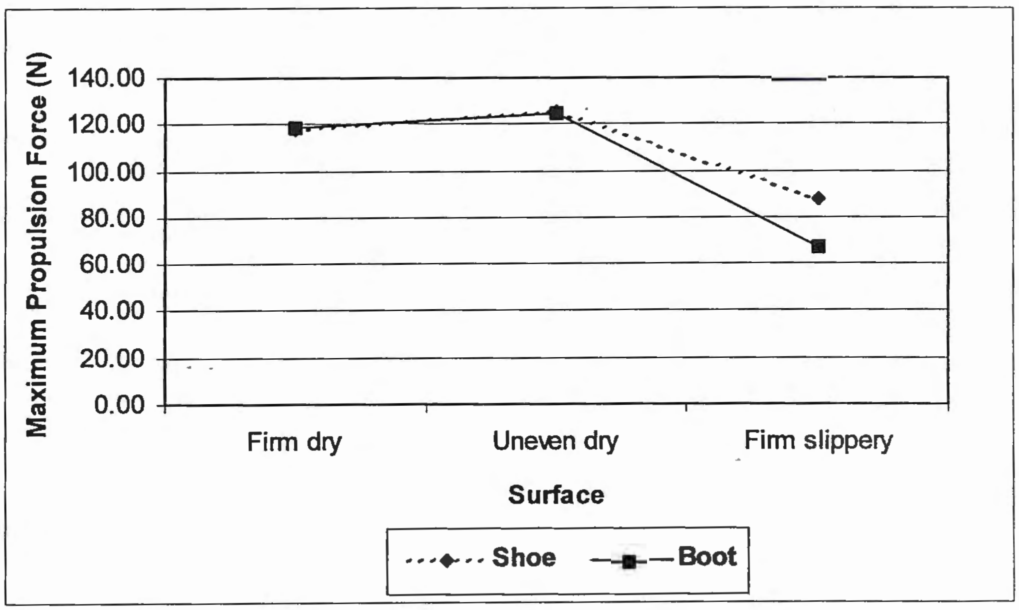


Figure V-3. Significant Interaction for of Surface and Footwear for Dynamic Postural Balance GRR – Maximum Propulsion Force.

Table V-4. Least Square Means of Significant Dynamic Postural Balance GRR – Maximum Lateral Force variables.

GRR - Maximum Lateral Force	Category	Mean	Standard Error
surface	Firm dry	-45.66	3.80
	Uneven dry	-62.32	3.81
	Firm slippery	-33.84	3.81

Table V-5. Least Square Means of Significant Dynamic Postural Balance GRR – Medial/Lateral Power variables.

GRR - Medial/Lateral Power	Category		Mean	Standard Error
surface	Firm dry		45.53	1.97
	Uneven dry		48.44	2.11
	Firm slippery		29.21	1.99
footwear	Shoe		43.05	1.84
	Boot		39.07	1.85
surface*footwear	Firm dry	Shoe	44.97	2.37
surface*footwear	Firm dry	Boot	46.09	2.36
surface*footwear	Uneven dry	Shoe	48.03	2.54
surface*footwear	Uneven dry	Boot	48.84	2.58
surface*footwear	Firm slippery	Shoe	36.14	2.39
surface*footwear	Firm slippery	Boot	22.27	2.38

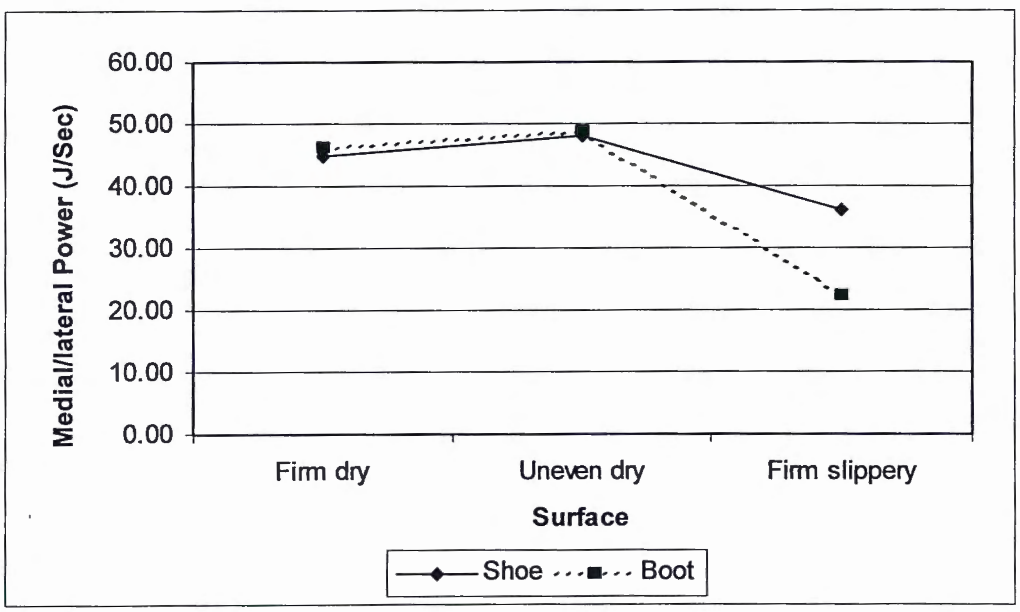


Figure V-4. Significant Interaction of Surface and Footwear for Dynamic Postural Balance GRR – Medial/Lateral Power.

Table V-6. Least Square Means of Significant Dynamic Postural Balance GRR – Brake/Propulsion Power variables.

GRR - Brake/Propulsion Power	Category		Mean	Standard Error
weight	Yes		52.02	4.29
	No		44.92	4.28
surface	Firm dry		54.93	4.37
	Uneven dry		66.01	4.38
	Firm slippery		24.47	4.38
footwear	Shoe		50.64	4.28
	Boot		46.30	4.28
surface*footwear	Firm dry	Shoe	55.46	4.64
surface*footwear	Firm dry	Boot	54.40	4.63
surface*footwear	Uneven dry	Shoe	64.85	4.63
surface*footwear	Uneven dry	Boot	67.17	4.65
surface*footwear	Firm slippery	Shoe	31.61	4.64
surface*footwear	Firm slippery	Boot	17.33	4.64

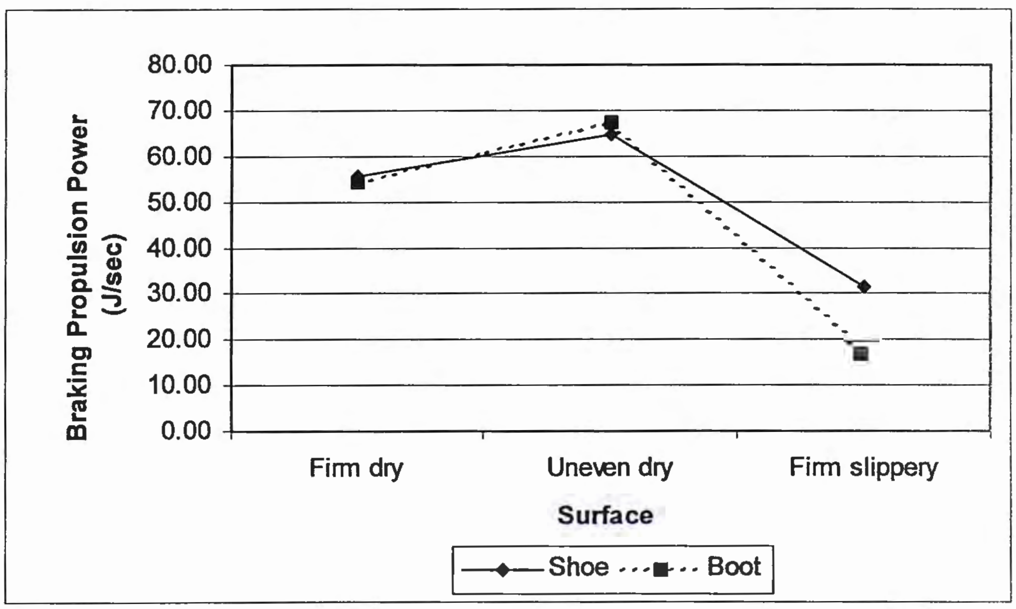


Figure V-5. Significant Interaction of Surface and Footwear for Dynamic Postural Balance GRR – Brake/Propulsion Power.

Table V-7. Least Square Means of Significant Dynamic Postural Balance GRR – Vertical Power variables.

GRR - Vertical Power	Category	Mean	Standard Error
weight	Yes	6817.96	400.27
	No	5340.19	400.09
surface	Firm dry	6090.91	403.74
	Uneven dry	6328.38	403.86
	Firm slippery	5817.93	403.86

Table V-8. Least Square Means of Significant Dynamic Postural Balance GRR – Maximum Positive Torque variables.

GRR - Maximum Positive Torque	Category		Mean	Standard Error
weight	Yes		7.87	0.52
	No		7.21	0.52
surface	Firm dry		8.43	0.54
	Uneven dry		10.57	0.54
	Firm slippery		3.61	0.54
footwear	Shoe		7.90	0.52
	Boot		7.18	0.52
surface*footwear	Firm dry	Shoe	9.13	0.59
surface*footwear	Firm dry	Boot	7.73	0.59
surface*footwear	Uneven dry	Shoe	10.33	0.60
surface*footwear	Uneven dry	Boot	10.81	0.60
surface*footwear	Firm slippery	Shoe	4.23	0.59
surface*footwear	Firm slippery	Boot	3.00	0.59

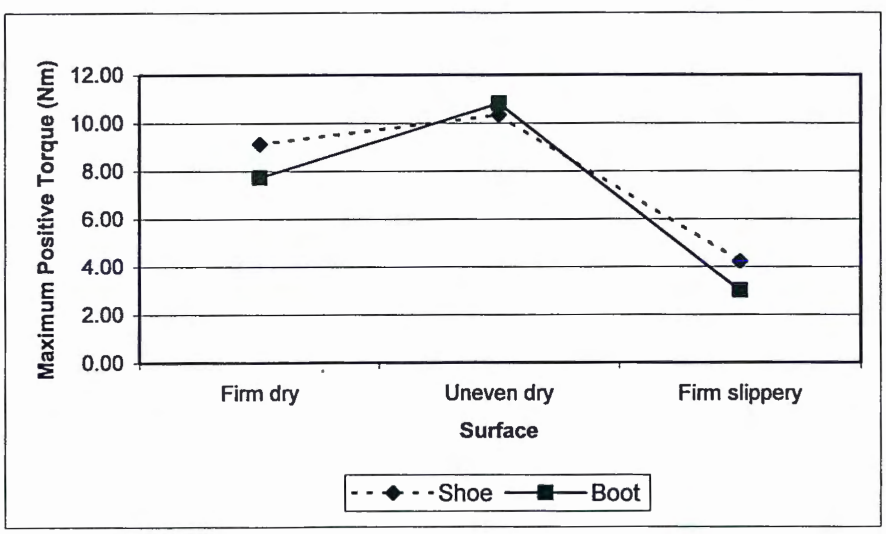


Figure V-6. Significant Interaction of Surface and Footwear for Dynamic Postural Balance GRR – Maximum Positive Torque.

Table V-9. Least Square Means of Significant Dynamic Postural Balance GRR – Maximum Negative Torque variables.

GRR - Maximum Negative Torque	Category		Mean	Standard Error
surface	Firm dry		-8.04	0.70
	Uneven dry		-9.40	0.73
	Firm slippery		-3.35	0.71
surface*footwear	Firm dry	Shoe	-7.94	0.78
surface*footwear	Firm dry	Boot	-8.14	0.78
surface*footwear	Uneven dry	Shoe	-8.33	0.82
surface*footwear	Uneven dry	Boot	-10.46	0.83
surface*footwear	Firm slippery	Shoe	-3.88	0.79
surface*footwear	Firm slippery	Boot	-2.83	0.79

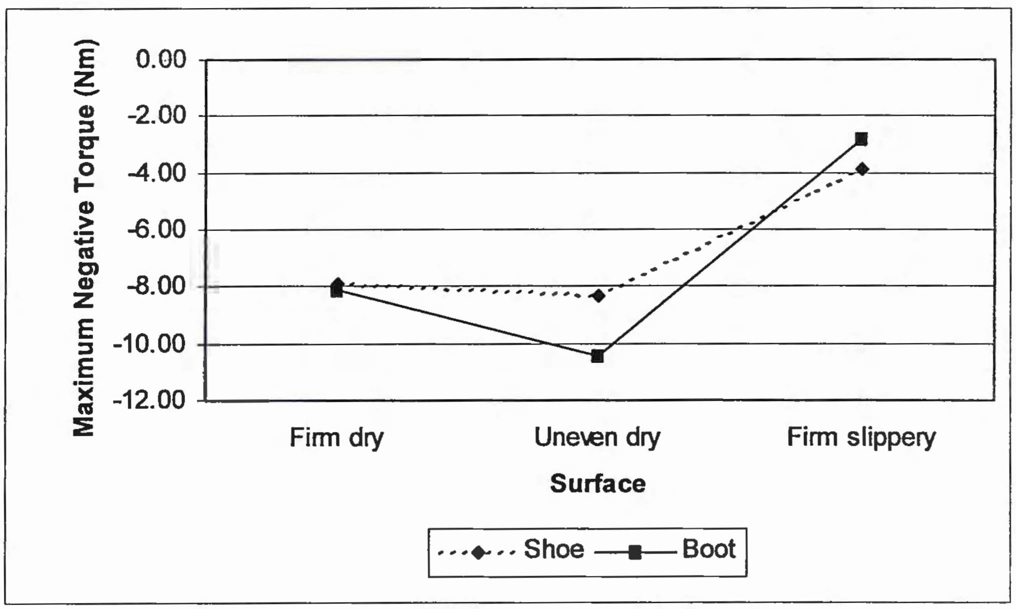


Figure V-7. Significant Interaction of Surface and Footwear for Dynamic Postural Balance GRR – Maximum Negative Torque.

Table V-10. Least Square Means of Significant Dynamic Postural Balance GRR – Contact Time variables.

GRR - Contact Time	Category	Mean	Standard Error
weight	Yes	1.58	0.10
	No	1.40	0.10
surface	Firm dry	1.42	0.10
	Uneven dry	1.51	0.10
	Firm slippery	1.53	0.10

Table V-11. Least Square Means of Significant Dynamic Postural Balance GRR – Vertical Decay Rate variables.

GRR - Vertical Decay Rate	Category	Mean	Standard Error
footwear	Shoe	1200.53	84.85
	Boot	1351.66	84.87

APPENDIX W

Ground Reaction Forces of Left Foot (GRL) outcomes

Table W-1. Least Square Means of Significant Dynamic Postural Balance GRL – Maximum Medial Force variables.

GRL - Maximum Medial Force	Category		Mean	Standard Error
surface	Firm dry		-136.73	5.63
	Uneven dry		-138.47	5.70
	Firm slippery		-100.84	5.67
footwear	Shoe		-127.65	5.54
	Boot		-123.04	5.54
Regular Exercise	No		-98.46	7.13
	Yes		-152.23	13.63
surface*footwear	Firm dry	Shoe	-134.58	5.92
surface*footwear	Firm dry	Boot	-138.88	5.91
surface*footwear	Uneven dry	Shoe	-136.50	6.01
surface*footwear	Uneven dry	Boot	-140.44	6.04
surface*footwear	Firm slippery	Shoe	-111.87	5.95
surface*footwear	Firm slippery	Boot	-89.81	5.94

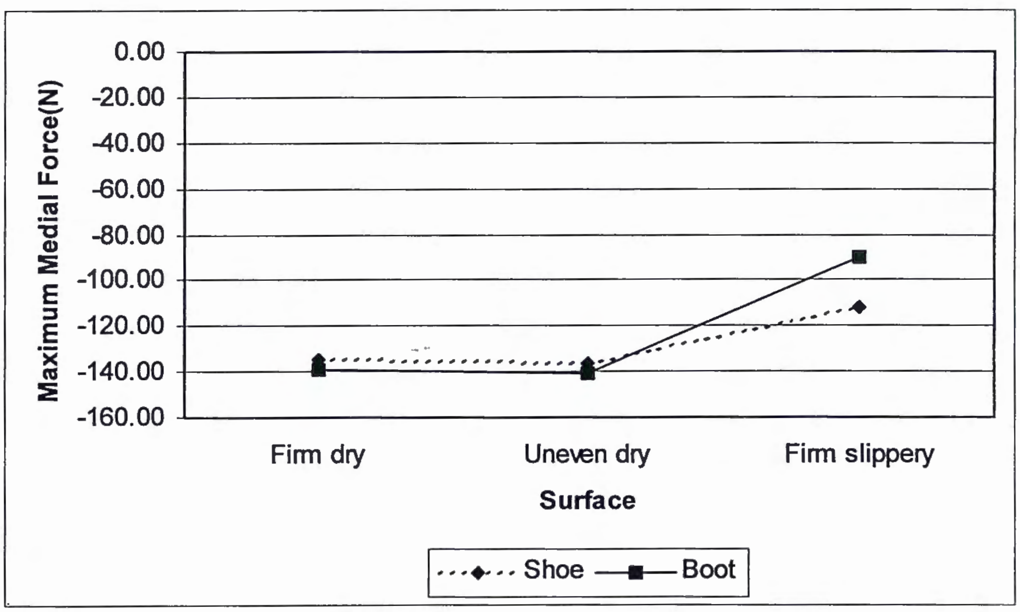


Figure W-1. Significant Interaction of Surface and Footwear for Dynamic Postural Balance GRL – Maximum Medial Force.

Table W-2. Least Square Means of Significant Dynamic Postural Balance GRL – Maximum Braking Force variables.

GRL - Maximum Braking Force	Category	Mean	Standard Error
weight	Yes	-128.38	6.51
	No	-113.12	6.50
surface	Firm dry	-129.53	6.87
	Uneven dry	-163.57	6.89
	Firm slippery	-69.15	6.87

Table W-3. Least Square Means of Significant Dynamic Postural Balance GRL – Maximum Propulsion Force variables.

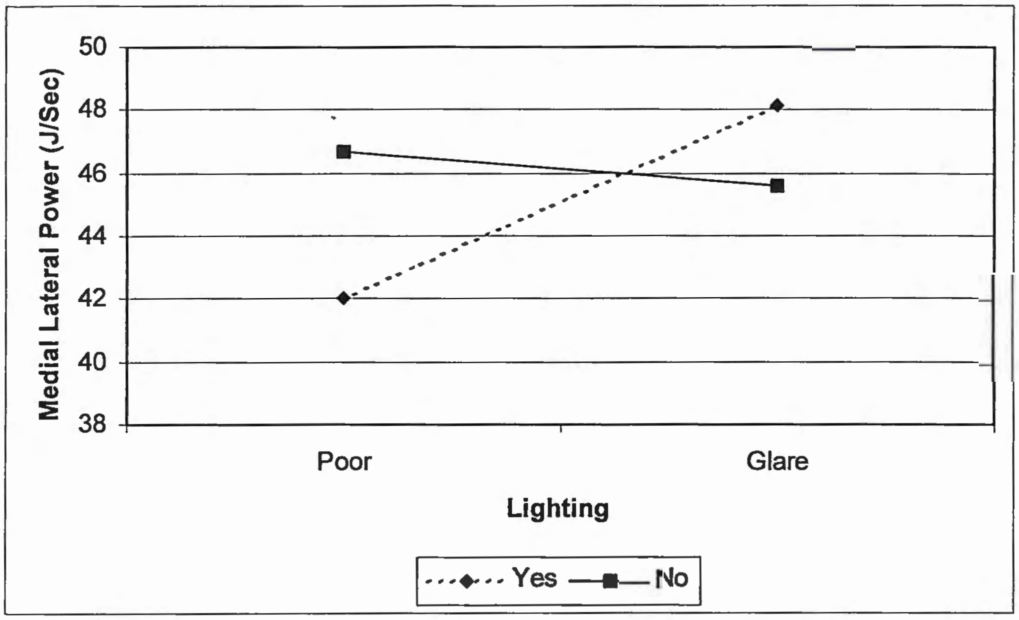
GRL - Maximum Propulsion Force	Category	Mean	Standard Error
weight	Yes	102.46	5.96
	No	94.76	5.95
surface	Firm dry	110.94	6.13
	Uneven dry	117.25	6.22
	Firm slippery	67.64	6.14
footwear	Shoe	103.39	5.95
	Boot	93.83	5.96

Table W-4. Least Square Means of Significant Dynamic Postural Balance GRL – Maximum Lateral Force variables.

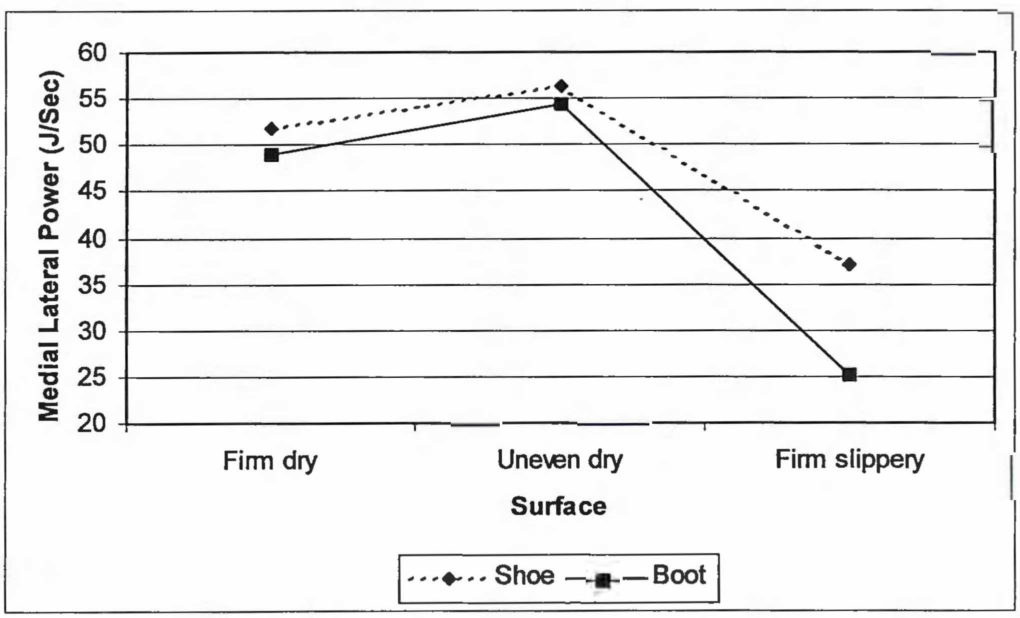
GRL - Maximum Lateral Force	Category	Mean	Standard Error
surface	Firm dry	44.92	2.24
	Uneven dry	61.39	2.25
	Firm slippery	32.23	2.24
mine type	Low Seam	26.16	4.04
	High Seam	53.43	3.08
	Above Ground/Strip	32.98	3.78
	Both Low and High Seam	58.54	2.59
	All (Low, High, Above/Strip)	59.80	5.04

Table W-5. Least Square Means of Significant Dynamic Postural Balance GRL – Medial/Lateral Power variables.

GRL - Medial/Lateral Power	Category		Mean	Standard Error
surface	Firm dry		50.37	1.76
	Uneven dry		55.39	1.77
	Firm slippery		31.08	1.76
footwear	Shoe		48.38	1.55
	Boot		42.85	1.56
weight*lighting	Yes	Poor	42.00	1.94
weight*lighting	Yes	Glare	48.15	1.97
weight*lighting	No	Poor	46.71	1.94
weight*lighting	No	Glare	45.60	1.94
surface*footwear	Firm dry	Shoe	51.77	2.28
surface*footwear	Firm dry	Boot	48.98	2.27
surface*footwear	Uneven dry	Shoe	56.31	2.27
surface*footwear	Uneven dry	Boot	54.47	2.30
surface*footwear	Firm slippery	Shoe	37.05	2.28
surface*footwear	Firm slippery	Boot	25.11	2.27



a. Interaction of Lighting and Weight for GRL – Medial/Lateral Power



b. Interaction of Surface and Footwear for GRL – Medial/Lateral Power

Figure W-2. Significant Interactions for Dynamic Postural Balance GRL – Medial/Lateral Power.

Table W-6. Least Square Means of Significant Dynamic Postural Balance GRL – Brake/Propulsion Power variables.

GRL - Brake/Propulsion Power	Category	Mean	Standard Error
weight	Yes	52.19	3.88
	No	40.47	3.87
surface	Firm dry	51.99	3.99
	Uneven dry	66.59	4.05
	Firm slippery	20.39	4.00

Table W-7. Least Square Means of Significant Dynamic Postural Balance GRL – Vertical Power variables.

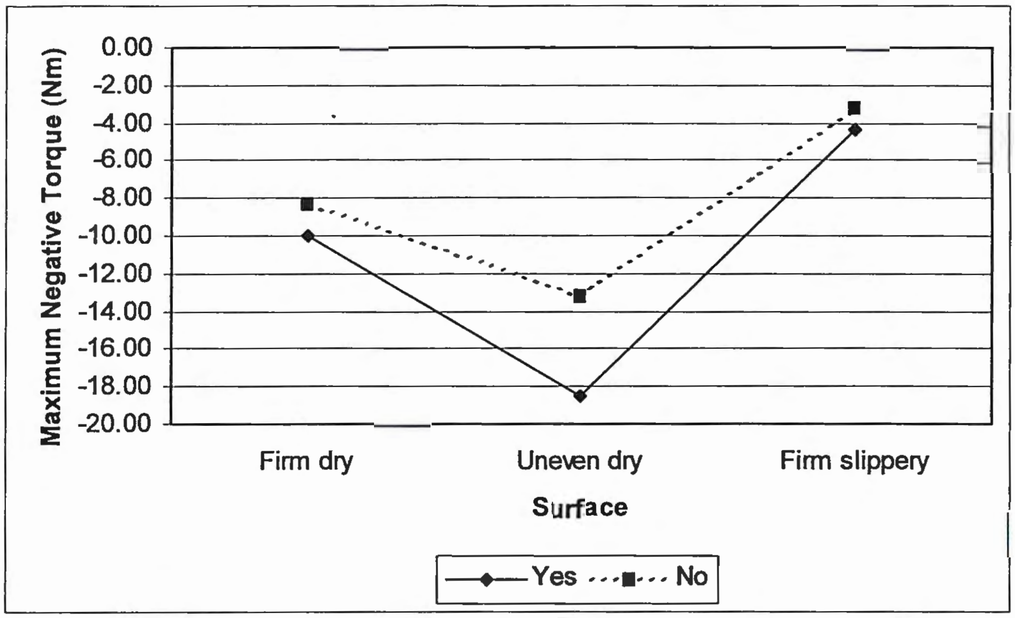
GRL - Vertical Power	Category	Mean	Standard Error
weight	Yes	7250.03	516.27
	No	5511.91	516.13
surface	Firm dry	5869.64	520.03
	Uneven dry	6566.33	520.16
	Firm slippery	6706.93	520.03

Table W-8. Least Square Means of Significant Dynamic Postural Balance GRL – Maximum Positive Torque variables.

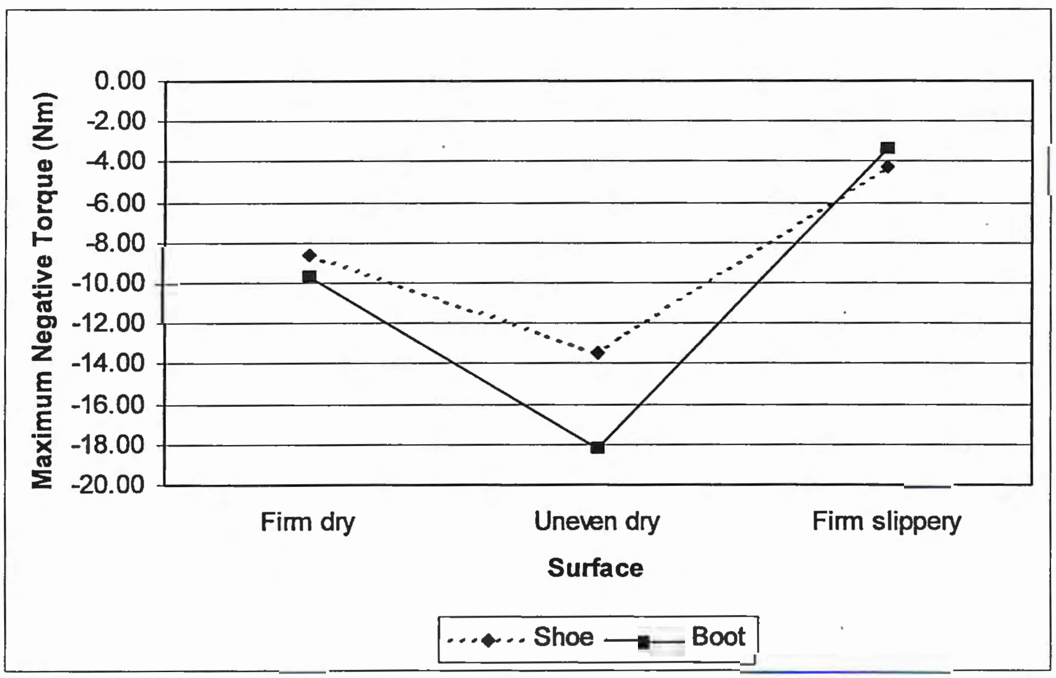
GRL - Maximum Positive Torque	Category	Mean	Standard Error
weight	Yes	12.26	0.98
	No	10.31	0.98
surface	Firm dry	10.75	1.04
	Uneven dry	17.05	1.04
	Firm slippery	6.05	1.04
footwear	Shoe	10.24	0.98
	Boot	12.33	0.98

Table W-9. Least Square Means of Significant Dynamic Postural Balance GRL – Maximum Negative Torque variables.

GRL - Maximum Negative Torque	Category		Mean	Standard Error
weight	Yes		-10.96	0.44
	No		-8.25	0.44
surface	Firm dry		-9.16	0.55
	Uneven dry		-15.87	0.56
	Firm slippery		-3.78	0.55
footwear	Shoe		-8.78	0.44
	Boot		-10.43	0.44
mine type	Low Seam		-8.81	0.74
	High Seam		-11.85	0.62
	Above Ground/Strip		-6.23	0.73
	Both Low and High Seam		-12.70	0.43
	All (Low, High, Above/Strip)		-8.42	0.95
weight*surface	Yes	Firm dry	-10.00	0.81
weight*surface	Yes	Uneven dry	-18.56	0.82
weight*surface	Yes	Firm slippery	-4.33	0.81
weight*surface	No	Firm dry	-8.31	0.80
weight*surface	No	Uneven dry	-13.19	0.80
weight*surface	No	Firm slippery	-3.24	0.80
surface*footwear	Firm dry	Shoe	-8.59	0.81
surface*footwear	Firm dry	Boot	-9.73	0.80
surface*footwear	Uneven dry	Shoe	-13.51	0.80
surface*footwear	Uneven dry	Boot	-18.23	0.82
surface*footwear	Firm slippery	Shoe	-4.25	0.81
surface*footwear	Firm slippery	Boot	-3.32	0.80



a. Interaction of Surface and Weight for GRL – Maximum Negative Torque



b. Interaction of Surface and Footwear for GRL – Maximum Negative Torque

Figure W-3. Significant Interactions for
Dynamic Postural Balance GRL – Maximum Negative Torque.

Table W-10. Least Square Means of Significant Dynamic Postural Balance GRL – Contact Time variables.

GRL - Contact Time	Category		Mean	Standard Error
weight	Yes		1.72	0.14
	No		1.47	0.14
surface	Firm dry		1.46	0.14
	Uneven dry		1.56	0.14
	Firm slippery		1.76	0.14
footwear	Shoe		1.55	0.14
	Boot		1.64	0.14
surface*footwear	Firm dry	Shoe	1.46	0.14
surface*footwear	Firm dry	Boot	1.45	0.14
surface*footwear	Uneven dry	Shoe	1.52	0.14
surface*footwear	Uneven dry	Boot	1.61	0.14
surface*footwear	Firm slippery	Shoe	1.66	0.14
surface*footwear	Firm slippery	Boot	1.87	0.14

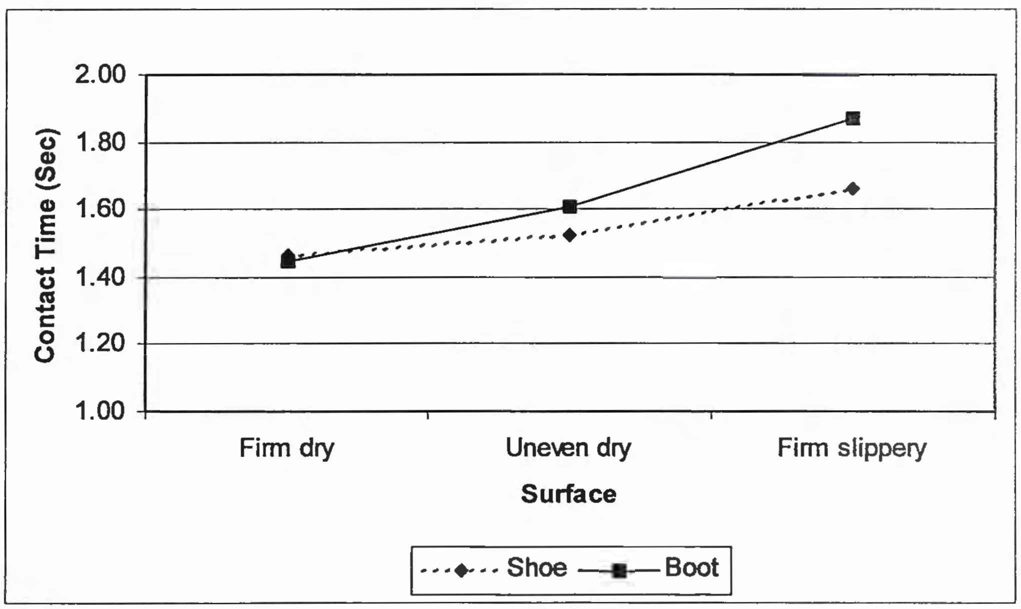


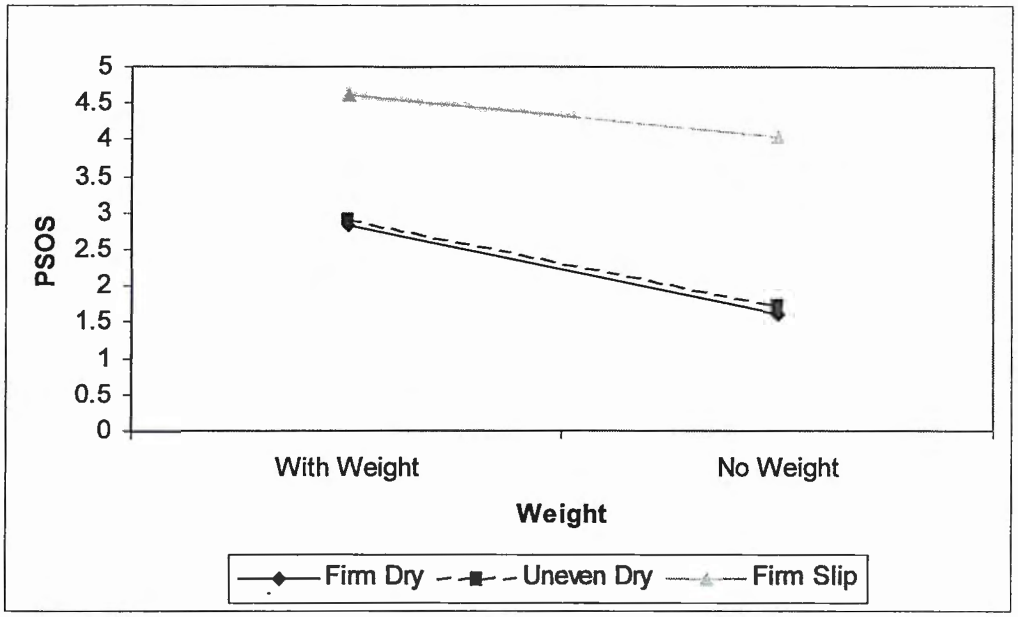
Figure W-4. Significant Interaction of Surface and Footwear for Dynamic Postural Balance GRL – Contact Time.

APPENDIX X

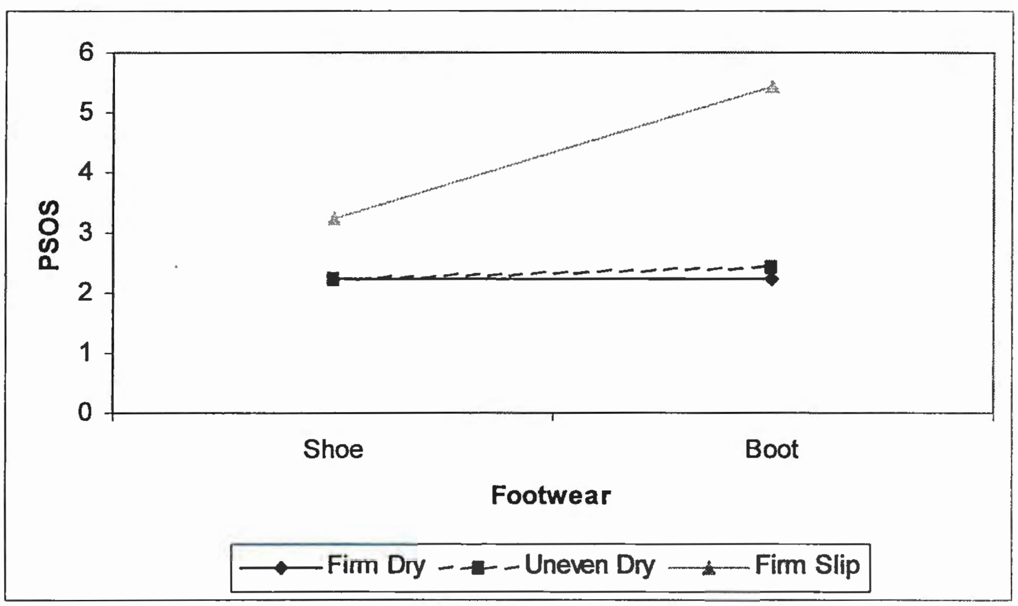
Perceived Exertion and PSOF outcomes for Dynamic balance tasks

Table X-1. Least Square Means of Significant Dynamic Postural Balance Perceived Sense of Slip (PSOS) variables.

Gait PSOS	Category		Mean	Standard Error
weight	Yes		3.46	0.41
	No		2.46	0.41
surface	Firm Dry		2.23	0.42
	Uneven Dry		2.32	0.42
	Firm Slip		4.33	0.42
footwear	Shoe		2.56	0.41
	Boot		3.36	0.41
weight*surface	with weight	Firm Dry	2.84	0.43
weight*surface	with weight	Uneven Dry	2.92	0.43
weight*surface	with weight	Firm Slip	4.62	0.43
weight*surface	no weight	Firm Dry	1.63	0.43
weight*surface	no weight	Uneven Dry	1.73	0.43
weight*surface	no weight	Firm Slip	4.03	0.43
surface*footwear	Firm Dry	Shoe	2.22	0.43
surface*footwear	Firm Dry	Boot	2.24	0.43
surface*footwear	Uneven Dry	Shoe	2.23	0.43
surface*footwear	Uneven Dry	Boot	2.42	0.43
surface*footwear	Firm Slip	Shoe	3.23	0.43
surface*footwear	Firm Slip	Boot	5.43	0.43



a. Interaction of Weight and Surface for Dynamic Postural Balance PSOS.



b. Interaction of Footwear and Surface for Dynamic Postural Balance PSOS.

Figure X-1. Significant Interactions for Dynamic Postural Balance PSOS.

Table X-2. Least Square Means of Significant Dynamic Postural Balance Rating of Perceived Exertion (RPE) variables.

Gait RPE	Category		Mean	Standard Error
weight	Yes		11.80	0.72
	No		9.79	0.72
surface	Firm Dry		10.42	0.72
	Uneven Dry		10.71	0.72
	Firm Slippery		11.27	0.72
footwear	Shoe		10.50	0.72
	Boot		11.09	0.72
surface*footwear	Firm Dry	Shoe	10.38	0.73
surface*footwear	Firm Dry	Boot	10.46	0.73
surface*footwear	Uneven Dry	Shoe	10.66	0.73
surface*footwear	Uneven Dry	Boot	10.76	0.73
surface*footwear	Firm Slip	Shoe	10.48	0.73
surface*footwear	Firm Slip	Boot	12.05	0.73

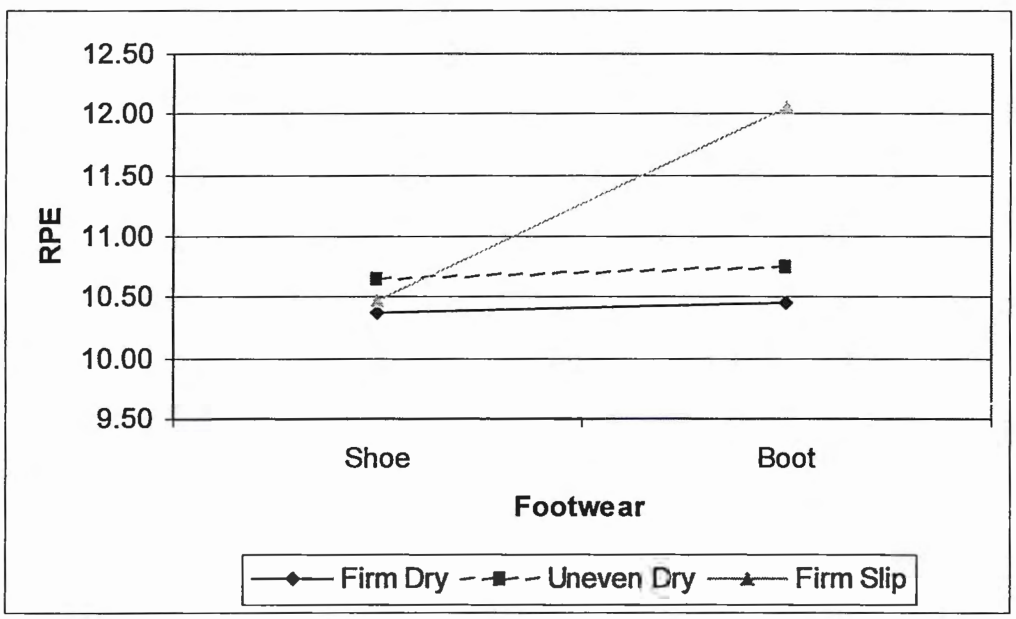


Figure X-2. Significant Interaction of Surface and Footwear for RPE.

APPENDIX Y

Slips and Falls during Dynamic balance tasks

Table Y-1. Odds Ratios of Significant Dynamic Postural Balance Observed Slips.

Weight1	Weight2	Odds Ratio
WEIGHT	NO WEIGHT	1.96

Footwear1	Footwear2	Odds Ratio
Leather shoe	Rubber boot	1.57

Surface1	Surface2	Odds Ratio
Uneven Dry	Firm Dry	2.66
Firm Slip	Firm Dry	66.40
Firm Slip	Uneven Dry	25.00

Table Y-2. Odds Ratios of Significant Dynamic Postural Balance Observed Falls.

Surface1	Surface2	Odds Ratio
Uneven Dry	Firm Dry	1.08
Firm Slip	Firm Dry	18.97
Firm Slip	Uneven Dry	17.51

Footwear1	Footwear2	Odds Ratio
Rubber boot	Leather shoe	5.68