Evaluation of Delta Balance Standing Platform

A Technical Report

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1. Executive Summary

The Delta Balance approach us to investigate scientifically and quantitatively the effect of the use of the Delta Balance standing platform used for patients of chronic low back pain.

An experiment was designed to study comparatively the study Delta Balance Platform (platform) use while standing on downward slope, horizontal surface, and upward slope. The study received ethics approval and 5 male and 5 female subjects were recruited. These subjects were required to stand on three surfaces for 5 minutes each.

Prior to the experimental session after subjects had signed informed consent form, they were weighed, measured and their ages were recorded. The subjects attired in briefs or two piece swim suits. After suitable skin preparation active differential electrodes were placed on the bellies of tibialis anterior, gastromenemii (medial and lateral), vastus lateralis, vastus medialis, hamstrings, lumbar erector spinae and thoracic lumbar spinae all on the right side of the body. For reference activities the subjects were required to stand on heels, toes, and full trunk flexion and subsequent extension. The EMG values for heel stand was used to normalized tibialis anterior (TA) and hamstrings (HM) toe stand for lateral gastrocnemius (LG) medial gastrocnemius (MG), vastus lateralis (VL) and vastus medialis (VM). Extension from flexed trunk posture was used to normalized lumbar erector spinae (l3) and thoracis erector spinae (T12).

The subjects were then asked to assume the three positions in a random order for five minutes in each position without moving their heads, torsos, arms or bending in any direction. A camera was placed in coronal plane at two meters to take profile picture at the start and at one minute interval.

The EMG data was sampled at 1024 kHz for a period of five minutes after preamplifying the signals at source by a factor of 10. The raw signals were passed through a band pass filter with lower end set of 20 Hz and the upper end set at 450 Hz. The signals were further amplified by a factor of 1,248 before recording on the computer hard disk. The amplifier was fully isolated and had a frequency response from DC to 5 kHz, common mode rejection ratio of 92 dB. Upon return to the laboratory the EMG signals were full wave rectified and linear envelope detection. The peak and average magnitudes were extracted in microvolts (uv) and normalized against the reference activity for the muscle in question. The raw data was used to carry out spectral analysis through Fast Fourier Transform Median frequency (MF), mean power frequency (MPF), total power (TP) and peak power (PP) for all muscles and for each of the three activities.

Using the photographs of all subjects, at every minute interval, the wrist, elbow, shoulder, hip, knee and elbow angles were measured. These angles along with the height, weight and gender of the subject was input into the University of Michigan biomechanical model. The analysis yielded lumbosacral compression and shear, L4/L5 compression and shear, and forces generated by the left and right L3, T12, rectus abdominis (RA), internal oblique (IO), external oblique and latissimus dorsi (LD).

These data were analyzed statistically to provide descriptive statistics of means and standard deviations. Subsequently, each of these variables was subjected to analysis of variance (ANOVA) to discern significant differences, if any.

Analysis revealed that the data throughout the five minute period of recording were not significantly different from each other. Hence all data for the five minute period were collapsed within the variable and mean values extracted. These represented the individual channel values for individuals. A global analysis of variance was carried out for all EMG variables and the two genders. The analysis revealed that there was no significant difference between males and females with respect to EMG variables except the median frequency. The data of two genders were pooled and subjected to ANOVA and multiple comparisons. The peak and average EMG both raw and normalized did not show significant difference between the three standing surfaces. However, when the EMG values were normalized against the down slope values and plotted the EMG magnitude (peak and average) the EMG output of all channels combined were lowest for the down slope standing. In frequency domain the peak power and total power also did not show significant difference between the three standing surfaces. However, the median frequency and the mean power frequency showed significant differences between the three standing surfaces ($p<0.05$). The down slope had values lower than horizontal as well as upslope values. The significance of this finding is that the muscles are firing at a lower frequency to maintain the standing posture in down slope condition.

Also, the mean total power and mean peak power for the downward slope were lower than the upslope as well as the horizontal values. A lack of significant difference in EMG magnitude data (peak and average EMG; and peak and total power) are thought likely due to overall very small muscle activity. Furthermore, normalizing such low values against reference activities which involved significant effort may have further masked the difference.

The biomechanical analysis yielded some more decisive values. The lumbosacral compressions were found to be significantly different between males and females ($p<0.001$) as well as between the three experimental conditions tested ($p<0.01$). The downward slope had significantly lower lumbosacral compression than horizontal ($p<0.009$) and lower than the upslope as well for males. The results were opposite for females. Standing on down slope generated significantly different forces in the erector spinae ($p<0.01$) from horizontal with a lower mean value. The up slope standing was close behind down slope standing. The rectus abdominis, internal and external obliques also generated significantly different forces while standing on down slope as compared to horizontal. In most cases the down slope standing generated lower forces. Therefore, it clearly demonstrates while standing down slope one reduces the EMG demands and lumbosacral compression in males while standing up slope provides similar advantage to females. The lumbosacral compression is the most important biomechanical variable related to causation of low back pain. A significant reduction in cumulative compressive load relieves the spine providing a scientific rationale for sustained use of this device to relieve chronic low back pain.

2. Acknowledgements

The authors will like to thank the volunteers who willingly donated their time for the study. Their cooperation was most valuable and without their assistance this project could not have been conducted. We will also like to thank Powercom for providing us space and financial assistance to carryout these experiments.

Shrawan Kumar and Yogesh Narayan

3. Problem Statement and Purpose

World Health Organization (1995) reported that two thirds of the entire population of the world above the age of 10 years spend one third of their life working. While work is advantageous, as it generates 21.3 trillion dollars which sustains socio-economic fabric of the society worldwide, it has some problems and hazards. Worldwide, 120 million injuries and accidents are reported annually. Majority of these injuries are musculoskeletal. The Alberta Human Resources and Employment (AHRE) reported 37,598 loss-time injuries for the year 2002 (AHRE 2003). Approximately, 80% of all these injuries were musculoskeletal and of these approximately 48% were overexertion. The trunk and back accounted for the majority of these injuries. In 1999 the Bureau of Labour Statistics reported nearly one million people reporting loss-time injuries annually (BLS 1999). The estimated WBC cost due to these injuries was from $13 to $20 billion annually. Accounting for the indirect costs the total costs rose to $45 to $54 billion annually. According to Praemer, Furner and Rice the data collected in 1995 show that the economic burden was as high as $215 billion. Unfortunately, such costs are not reported for Alberta and Canada. Given the similarities between the two societies and comparatively more liberal system in our country, it may not be surprising that our cost to this affliction may be proportionally higher than those for Americans.

Low back disorder risk has been established through epidemiological studies of work that involves heavy lifting, frequent bending and twisting, prolonged sitting, whole body vibration and other risk factors. A work-relatedness of these problems have been addressed at length by National Academy of Science (2001), Bernard and Fine (1997). The consensus from all sources is that low back pain is a common affliction and its lifetime prevalence has been estimated to be 70% for industrialized countries (Andersson 1981). Data presented by Snook (1982) and Webster and Snook (1994) suggest that the point prevalence of this problem in the United States accounted for 16% of workers compensation claims and 33% of the total claims cost. Epidemiological studies as well as natural and provincial statistical reports have shown that the low back pain problems vary significantly among different industrial sectors (Bigos, et al., 1986, Riihimaki, et al., 1989, AHRE 2003, Statistics Canada, 1985, BLS 1995).

There are many ways and sites at which low back pain may manifest itself, including muscular strain, ligamentous sprain, facet joint aberration, intradiscal pressure on annulus fibrosis, and vertebral end-plates or nerve roots. Muscle strain is probably the most common type of back pain. The most common form of back pain is non-specific and idiopathic. When counted individually the number of specific risk factors for low back pain are multiple. Hildebrandt (1987), counted a total of 98 risk factors. Many more have been added since then. The most prominent and dominant risk factors classified by Bernard and Fine (1997) are 1) heavy physical work, 2) lifting and forceful movements, 3) frequent bending and twisting including awkward postures, 4) whole body vibration, and 5) static work postures. It is also common experience that not every lift, forceful exertion, awkward posture, static work or whole body vibration results in this condition. It, however, can be inferred from all these described risk factors that they result in increasing the biomechancial load on the system. With this realization Kumar (1990) demonstrated that even in those people involved in heavy work, occasional lifting and awkward posture, it was the cumulative load that was the most important factor in determination of precipitation of low back pain. In a study of Alberta Social Services employed institutional aides, Kumar (1990) reported that they point prevalence of low back pain was 62.7%. When these institutional aides were separated in pain and no pain groups and their life time exposure to physical loads was quantified, it was found that the cumulative load (life time) had to exceed a threshold range of exposure before the pain was precipitated even though the two groups were not statistically different from each other in age, gender, nutritional intake, leisure activity , socio-economic status and some other criteria.

Subsequently, Kumar (2001) proposed four possible theories through which musculoskeletal injuries such as low back pain could be precipitated. The Cumulate Load Theory stated that musculoskeletal injuries precipitated when the cumulative load exceeds the threshold tissue tolerance. The biological tissues being viscoelastic tissues, their behaviour is time and strain rate dependent. Due to repeated loading the load bearing tissues undergo repeated deformation, and if the next loading does not provide sufficient recovery period it will begin to accumulate residual deformation. This has the role of decreasing the threshold at which injury can occur due to decreased cross sectional area of the tissue and increase the stress concentration as the external load does not decline. Such an interaction of the load and tissue deformation potentiate precipitation of injury. The Differential Fatigue Theory (Kumar 2001) suggested that the majority of work related activities are asymmetrical and repetitious. This then will cause differential fatigue of the tissues due to differences in their geometry, cross sectional areas, points of origin and attachment, and proportionally different mechanical load with a tendency for it to accumulate disproportionately in some of the smaller/weaker tissues resulting in injury. The phenomenon of differential fatigue was experimentally demonstrated by Kumar and Narayan (1998) and Kumar et al (2001). The Overexertion Theory explained the tissue failure due to overexertion in symmetric or asymmetric activities either by a single large loading or a repeated loading. The difference between the cumulative load and overexertion lies in the relative magnitude of mechanical loads endured by the system, being larger for the Overexertion Theory. The rationale of the Overexertion Theory and method of determination of overexertion is detailed in Kumar (1994). Finally, the Multivariate Interaction Theory provides a rationale and pathway for genetic, morphological and psychosocial factors to modulate the precipitation of injury in occupational biomechanical milieu. However, a careful consideration of all proposed theories reveals that biomechanical factors are essential for injury to precipitate through any mechanism. All other factors may play a role in facilitating modulation of injury.

Most frequently, epidemiological studies consider the following categories of risk factors:

1. heavy physical work
2. lifting and forceful movements
3. bending and twisting (awkward postures)
4. whole body vibration and
5. static work postures

In each of the five foregoing categories there is a large number of studies. Here a small sample is presented to provide published evidence. Bergenuld and Nilson (1988) followed a Swedish population based cohort established in 1938. They used questionnaires to self assess as of 1983; exposure (light, moderate, heavy physical work). The results showed that those with moderate to heavy job demands had more back pain than those with light work (odds ratio 1:1.83, 95% confidence interval (CI) 1.2-2.7). Burdorf and Zondervan (1990) in their cross sectional study compared 33 mail crane operators with another 33 workers from the same company who did not operate cranes. Exposure was assessed through a questionnaire. The authors found that the crane operators were significantly more likely to suffer low back pain (odds ratio of 1:3.6). On the basis of these studies and many other (not reviewed here) it would appear that low back pain is associated with heavy physical work.

For lifting and forceful movements Punnett et al., (1991) reported a case control study where the authors examined the relationship between back pain and occupational exposure to load. The 95 back pain cases were interviewed and medically examined. They used as controls the workers without low back pain. Additionally, the jobs were videotaped. The peak biomechanical forces and duration spent in each posture were obtained. In their multivariate analysis which adjusted for covariates the authors found that lifting was associated with low back pain with odds ratio of 2.16. However, time spent in non neutral postures was strongly associated with low back pain with odds ratio of 8.09. Kumar (1990) studied 171 institutional aides employed in an extended care facility run by the Social Services of the Alberta Government. The author found that the aides were frequently involved in lifting, positioning, toileting and recreating the permanent severely disabled wards of the State. In this organization the point prevalence of low back pain was 72%. The pain and no pain groups were involved in identical occupational activities. Further, the two groups were not significantly different from each other in age, gender, nutritional status, leisure and recreational activities and socioeconomic status. The authors analyzed the jobs biomechanically using a biomechanical model. The previous jobs which the subjects had taken with their duration and specific tasks performed were also analyzed. The job history was also taken to determine the amount of time spent in each job. Each of these jobs were videotaped and analyzed biomechanically using the anthropometric values of the subjects in the study. The results indicated that though there was no significant difference between the pain and no pain groups in the current job, the pain group had done more lifting and physically demanding tasks in their previous jobs resulting in overall significantly higher cumulative load. There are numerous other studies which have reported similar results. Therefore, there is a strong cumulative evidence that low back pain is associated with work related lifting and forceful movements.

Bending, twisting and awkward postures have also been strongly associated with low back pain. Punnett et al., (1991) reported a case control study which examined this association. In a sample of 95 back pain cases from an auto assembly plant, exposure to awkward posture was measured through videotape and peak biomechanical forces were estimated for up to nine postures. After a multivariate analysis, adjusting for covariates, the awkward postures were found strongly associated with back disorder with an odds ration of 8.0. Burdorf et al., (1991), investigated back pain in male concrete fabrication workers using maintenance workers as controls. After posture analysis the authors found that concrete workers experienced significantly more back pain symptoms than the maintenance workers with an odds ratio of 2.8. Literature has numerous other studies which have reported a strong association between awkward postures including bending and twisting and low back pain.

Low back pain has been found associated with awkward and static postures. Burdorf and Zondervan (1990) looked into crane operators and compared them to other workers in the same company who did not do any crane operating. They examined the activities in the current and past work obtained through questionnaires. They rated the exposures according to the levels of, among other things, prolonged sedentary posture. They found that crane operators were significantly more likely to experience low back pain with an odds ratio of 3.6. Videman et al., (1990) reported the results of discography and radiography of discs of 86 male patients who died of unrelated causes. Subject symptoms and work exposures were determined by interview of family members. Among sedentary workers the disc degeneration risk was very high (odds ratio 24.6) as compared to those involved in heavy work (odds ratio 2.8). Other pathologies such as facet joint arthritis and endplate pathologies the sedentary workers were found to be at a much higher risk.

From the foregoing, it is evident that all primary risk factors have a significant "mechanical load on the spine" component. Clearly one can divide risk factors along the lines of activities or movements, but in the end it is the biomechanical loading that appears to be the common denominator. Also, it is evident that for common life or occupational activity there is difficulty in establishing dose response relationship. This mechanical load deformation relationship to failure cannot be tested in humans, though it has been demonstrated in cadaveric materials. There are several problems in such determination. First and foremost, we apply a simplistic logic to a very complex and dynamic tissue. We want to know the effect of submaximal loading akin to real life activities in a form interpretable as a response of a Hookean body. Clearly, this is impossible and scientists have felt frustrated. The difference between Hookean bodies of biological tissues are enormous. Not only that, biological tissue is viscoelastic with time and strain rate and time dependent mechanical properties, they are also dynamic in their biochemical nature with a potential to change the very properties we are seeking. Regardless of issues and debate on mechanical properties of spinal tissues, a better management of the mechanical loading, according to the biological principles, to optimize function is likely to be the most desirable way to proceed.

The former statement assumes a prominent role also because the medical model fails in back pain problems. It is common to find significant spinal pathology with no symptoms and symptomatic spines with no pathology. Such an observation provides further credence to the idea that at least majority of low back pain is a mechanical phenomena. Hence, it appears logical to consider mechanical solution to the problem. Elimination of mechanical load altogether from the spine is undesirable as it deconditions the structures, weakening them for further problems as well as making the individual less functional in life.

4. Objectives

Hence, the objectives of this study was to test a device for its mechanical impact on human spine as measured by a) spinal loading and b) EMG activities of lower extremity and spinal muscles.

5. Methods

a. Sample: The sample consisted of ten subjects five male and five female. All subjects were young ranging between 20 years and 38 years of age. None of them had back pain in the past year requiring one week time away from work. None of them had any musculoskeletal pain at the time of the study. Their ages, heights and weights are presented in Table 1. The experiment was approved by the Health Research Ethics Board and all volunteers signed the informed consent prior to proceeding with the experiment. No remuneration for subject participation was provided.

b. Tasks: the female subjects were required to dress up in sleeveless t-shirt and shorts (or two piece swim suit). The male subjects were asked to attire themselves in a brief or boxer shorts. After suitable preparation for data collection the subjects were asked to stand still in a posture comfortable for them on the Delta Balance Platform upslope, down slope and on horizontal floor, in a random order for a period of five minutes each. The subjects were instructed that during the five minute experimental standing period they were not allowed to talk, shuffle their feet, move or rotate their head or torso in any direction. Also, they were given a spot on the wall where they gazed for the entire five minute testing period.

c. Devices

i) Delta Balance Standing Platform. The Delta Balance Standing Platform (DBSP) is fashioned like a broad and shallow cone. The elevation of the surface from the horizontal is 15° in the form of a circular disc (figure 1). This disc is constructed of metal to keep the shape but is lined by a thick, uniform thickness, rubbery material on the top for insulation and providing grip for the feet.

ii) Photographic Equipment: A digital still camera mounted on a tripod stand at a fixed distance was used to take pictures of standing subjects in profile. The Sony DSC-S85 with an image resolution of 2272 x 1704 pixels and lens with focal length 34-102 mm (35 mm equivalent) equipped with an internal flash (range 3 m) was used.

iii) EMG Equipment: The Bagnoli-8 EMG system was used for EMG data collection. The active double differential electrodes are specifically designed to detect EMG signals from the skin surface while rejecting motion and cable artifacts. This eight-channel system with an overall amplification of 10,000 times, frequency response 20 Hz to 450 Hz with 12 dB/octave was used. The electrodes were three silver bars (1 mm x 10 mm) in double differential configuration with on site amplification of 10 and a bandwidth DC-700 kHz, CMMR 92dB and noise of less than 1.2 μV (rms). The amplifier system was fully isolated.

iv) Data Acquisition System: A Dell Inspiron 8200 with National Instrument PCMCIA data acquision card was used for data acquisition. The computer was loaded with the Ergonomics

Research Laboratory (ERL) data acquision software and ERL developed software for EMG data analysis.

d) Experimental Procedure: After signing the consent form the subjects were measured and weighed and their ages recorded. The muscle bellies of lateral and medial gastrocnemius, tibialis anterior, vastus lateralis, vastus medialis and hamstring muscles were identified and marked. Similarly the erectores spinae at 12th thoracic vertebral level (T12) and the third lumbar vertebral level were marked. All muscles selected were on the right side of the body. These selected areas were cleansed with a mixture of ethyl alcohol and acetone to remove dead skin and surface grease. In case of presence of hair the area was shaved prior to proceeding with the skin preparation. The knife-edge active surface electrodes were applied to identified and prepared skin and the integrity of the EMG system tested. Subsequently, the baseline activity was recorded in quiet standing (figure 2). The subjects were required to perform three normalization activities as described below:

i) Standing on toes. While taking support of a wall the subjects were asked to stand on their toes as high as they could. Once they had reached their maximal level a 5 s EMG recording was made to serve as the normalizing values for gastrocs and hamstrings (figure 3).

ii) Heel stand. Again taking support of the wall subjects were asked to stand on their toes as high as they could. Once they reached their maximal level a 5 s recording of EMG was made. The EMG's from this activity was used as a normalizing factor for tibialis anterior, vastus lateralis and vastus medialis (figure 4).

iii) Trunk extension. The subjects were asked to undergo deep flexion of their trunk in upright posture. Once they reached this posture data recording was initiated and subjects were asked to extend their trunk to upright position. These EMG traces were used to normalize the erectores spinae EMG at T12 and L3 levels (figure 5).

Once the base line activity and normalizing activities were recorded the subjects were asked to stand on horizontal floor surface, upslope and down slope on the DBSP in a random order for five minutes. The subjects were instructed to focus on a spot on the wall without moving their head, arms, torso or any other part of the body for the entire five minutes. Once a position was completed, the subjects were provided a chair to sit on for a few minutes. During this duration the quality and integrity of recorded data was checked for the entire 300 s period. Upon satisfaction the experiment proceeded to the next randomly chosen condition. During the 300 s experimental period still pictures of subjects were taken at the start of the condition and every minute thereafter to a total of six pictures per condition. These pictures were taken by a high resolution digital camera placed on 2 m away from the subject on a tripod stand placed at marked position on floor.

e) Data Acquisition

i) EMG data. The EMG data were acquired using a DELL laptop equipped with a National Instrument PCMCIA card. The double differentiated EMG signals were preamplified by a factor of 10 on site before proceeding to the waist mounted amplifier with a gain factor of 1000. The EMG and amplifier system was fully isolated and the subjects were grounded. The EMG signals were passed through a 60 Hz notch filter. The sampling frequency was 1024 Hz.

ii) Postural Data. The captured EMG were transferred to the computer and the joint centres of ankle, knee, hip, shoulder, elbow and wrist were marked. A specially written joint marking program developed at the Ergonomics Research Laboratory calculated the angles at each joint and formatted the data ready to be inputted into the University of Michigan biomechanical model.

f) Data Analysis

i) EMG Analysis. The EMG data collected were examined and analyzed for each channel separately before a comprehensive analysis. These EMG traces were applied a 7-point moving average smoothing with one repetition. Such smoothed traces subjected to magnitude and frequency domain analysis. For magnitude analysis the signals were full wave rectified and linear envelope detected using 25 ms time constant. At this stage, EMG magnitude analysis program developed at the Ergonomics Research Laboratory was applied to determine the peak EMG, average EMG and normalized peak and average EMG of all

Figure 7. Posture, spinal load analysis with Biomechanical Model.

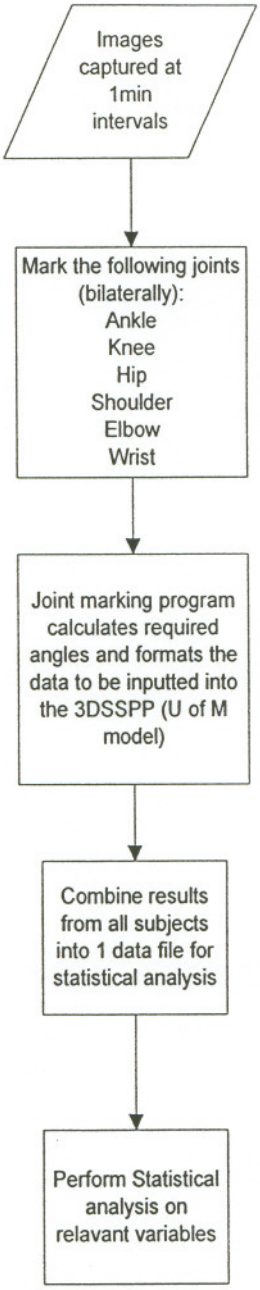


Figure 8. Normalized peak and average EMG activity during standing on three surfaces.

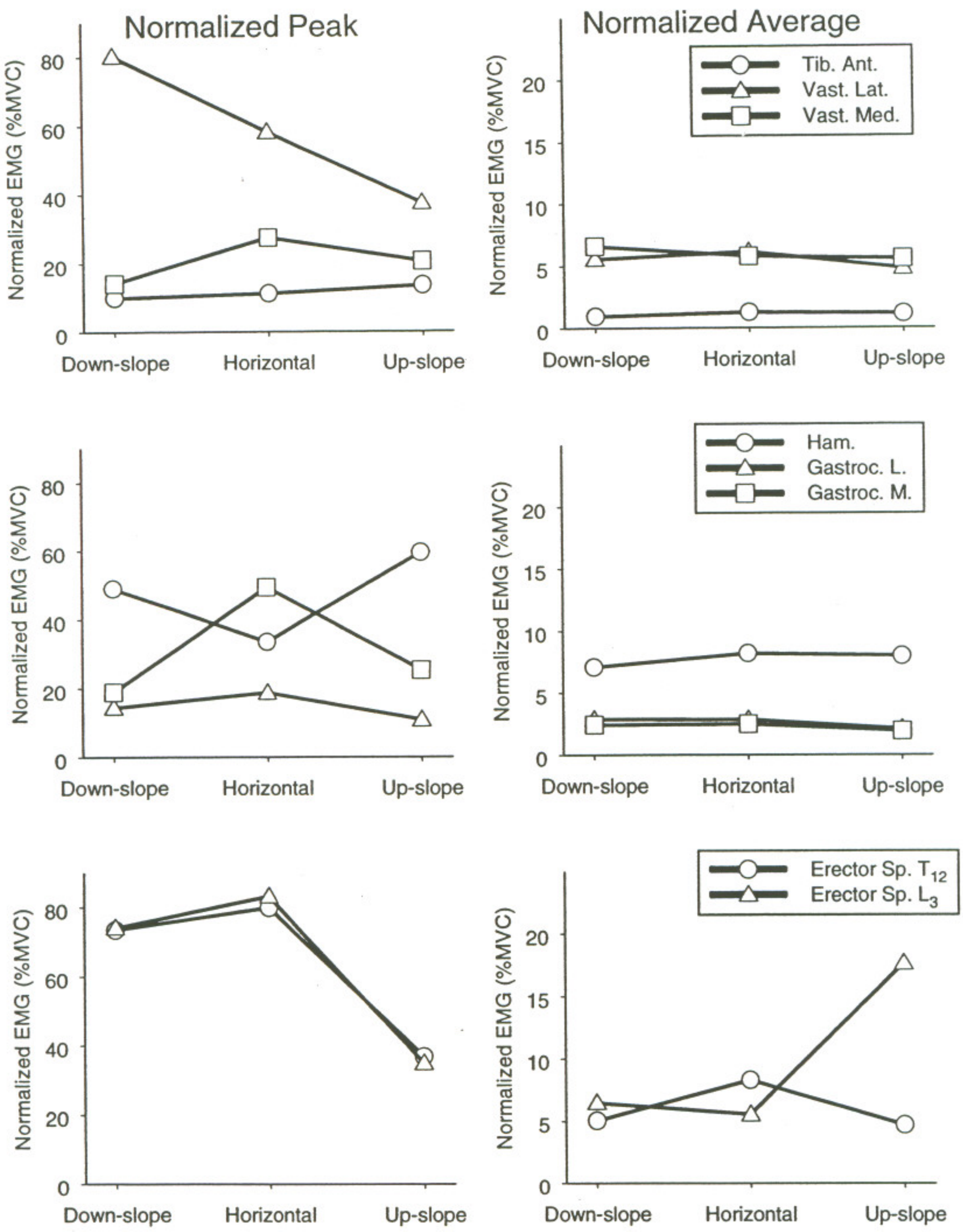
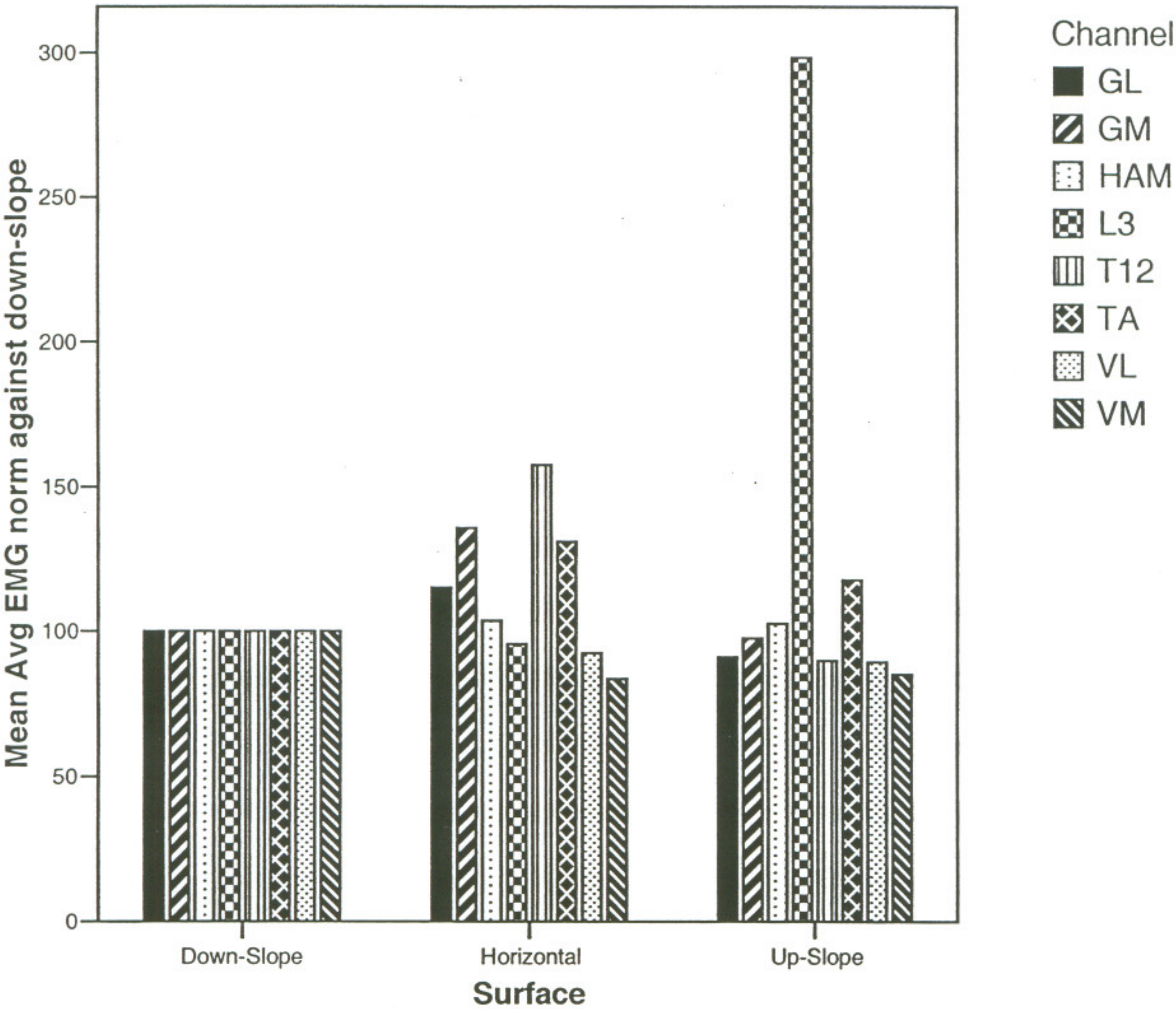


Figure 9. Horizontal and up-slope mean average EMG values normalized against the down slope values (%).



channels. These magnitudes were then compared across trial conditions for magnitude difference. Also relative magnitude differences were depicted by normalizing the horizontal surface and upslope data against the down slope reference value. For frequency domain analysis the smoothed data were subjected to Fast Fourier Transform (FFT) analysis to obtain the median frequency (MF), mean power frequency (MPF), peak power (PP) and total power (TP) for each of the muscles in each of the tested conditions. The analog algorithm of the data analysis of EMG signals is presented in figure 6.

For statistical analysis all EMG data were combined in one file. Minute averages of all channels were calculated and first to 5th minute data were compared. Since no statistically significant differences were found the data were collapsed over time for further analysis. Finally, a multivariate analysis of variance was conducted to discern differences, if any, between the three standing surface, two genders, eight muscles and any interaction between the variables. Additionally, a multiple comparison was performed to discern differences between the three standing surfaces studied.

ii) Posture and spinal load analysis: The postural data in the form of the joint angles at wrist, elbow, shoulder, hip, knee, and ankle along with the subject's height and weight were inputted into the University of Michigan 3 D static strength prediction program to determine lumbosacral compression and sagittal shear. In addition, we obtained the resultant forces in erectores spinae, latissimus dorsi, rectus abdominis, external and internal obliques during standing on three surfaces at each minute. Subsequently, each minute values were compared within variables for any statistical differences. Finding none, the data were collapsed over time and subjected to analysis of variance and multiple comparisons to discern differences between three different surfaces. The algorithm of the procedure is presented in figure 7.

6. RESULTS

a) EMG Results

i) Magnitude: Since the initial global analysis revealed no gender difference in EMG values the data for the two genders were collapsed. The peak and average EMG in microvolt for each of the channels while standing on three surfaces are presented in Table 2. These were then normalized against their respective referent values and are presented in Table 3. Both normalized peak and average EMG values are plotted in figure 8. An examination of the results indicates that whereas the peak erectores spinae values were lowest in upslope and highest in horizontal surface condition. The average values showed an altogether different pattern. Here the L3 erectores spinae have 6% score in down slope as opposed to 17% in upslope. At T12 level though both down slope and up slope values are low. The results present somewhat varying picture. Also, it is worthy of note that the standard deviations for the peak values were very high. With respect to the lower limb muscle activities generally the gastrocnemius values were lower in down slope compared to horizontal, hamstring, lowest in horizontal condition. The tibialis anterior had lowest score in down slope. Vastus lateralis and vastus medialis were opposite to each other.

The normalized mean average EMG activities presented a little more physiologically consistent responses. Gastrocnemius muscles had a little higher score for down slope and horizontal as compared to up slope. Hamstring showed lowest score for down slope. Erectores spinae at both levels L3 and T12 had little demand in down slope. Since the average scores are average of the entire trial, perhaps they could be more representative of the actual phenomenon. Also the peak scores can be significantly influenced by any effort of a postural adjustment, howsoever small.

When the EMG magnitude data for the three surfaces were normalized against the down slope value, again an interesting pattern emerged (table 4, and figures 9 and 10). The total EMG output when averaged over all channels appeared marginally lower for the down slope values. Also the combined mean average EMG of erectores spinae activity was marginally lower than those of horizontal or up slope surfaces.

An analysis of variance carried out for the mean peak and mean average EMG values showed no significant results. There was no significant difference between genders or surfaces on which subjects stood (tables 5 and 6). Identical result was obtained when the horizontal and up slope EMG mean peak and mean average amplitudes were normalized against down slope values (tables 7 and 8).

ii) Frequency Domain Analysis: In frequency domain parameters the global ANOVA showed significant differences between the genders, hence these results will be presented for both genders. The median and mean power frequencies for males and females are presented in table 9 and figures 11 and 12. Those results show that while the mean median frequency and mean power frequency for males were similar for down slope and horizontal surfaces, the up slope was significantly higher. On the contrary among females the horizontal surface was lowest for both MF and MPF followed by the other two surfaces.

Since there were no significant differences between genders for the total power and peak power the data were not split by gender and are presented in Table 10. Though there are significant differences, they do not appear to systematic. When these values were normalized against the down slope both MF and MPF were marginally lower in horizontal compared to the down slope, both were significantly lower than the up slope (table 11a). Table 11b presents the total power and the peak power normalized against the down slope values. Figures 14A and B show that the total power and the peak power were significantly lower in down slope standing compared to horizontal or up slope stand.

The ANOVA summary table of the MF in males showed a difference between surfaces but not in females. A further multiple comparison revealed that actually the down slope had the highest value followed by the horizontal and then the up slope (tables 12 and 13). A similar result was found for the Mean Power Frequency as well (tables 14 and 15). An analysis of variance for median frequency and mean power frequency normalized against down slope values showed a significant main effect for both gender and surface ($p<0.03$), (tables 16 and 17). A multiple comparison by post hoc test revealed that down slope had the highest mean value for both variables. The horizontal surface was not significantly different from the down slope, but both down slope and horizontal surfaces were significantly different from the up slope ($P<0.04$) (tables 18 and 19). The total power and peak power did not reveal any significant differences and main effects for gender or standing surfaces (tables 20 and 21). Due to a significant difference observed between genders the data was split along gender and reanalyzed for the Median Frequency and Mean Power Frequency and normalized against the down slope (table 22 and figures 15 and 16). The results demonstrate that both median frequency and mean power frequency were less for horizontal surface from the down slope. The up slope values were significantly greater than the other two surfaces. The ANOVA of the Median Frequency and Mean Power Frequency both demonstrated significant main effects due to surface in both males and females ($P<0.03$ to 0.009) (tables 23 and 24). The Scheffe post hoc test for multiple comparison revealed that only horizontal surface in female was significantly different from the up slope for median frequency ($P<0.01$) and for mean power frequency ($P<0.009$).

B Biomechanical Load Analysis

The output of the biomechanical model provided the lumobsacral compression and shear, and compression at the L4/L5 joint as presented in Table 25 and figure 17. The males and females demonstrate divergent response. While among males lumbosacral as well as L4/L5 compressions were least in down slope standing, the females had lowest compression in horizontal closely followed by the up slope at L/S and from down slope at L4/L5. However, these compressive and shear loads were of very low order. In these standing postures the forces generated by dorsal muscles are presented in Table 26 and those by ventral muscles are presented in Table 27 and Figures 18 and 19. There was a divergence between males and females with respect to forces generated by dorsal muscles in down slope and up slope (figure 18). In up slope the females showed the least force but the males showed the most. For down slope the males demonstrated lower values than those by the females. For the ventral muscles both genders demonstrated least forces in down slope (figure 19).

An analysis of variance for lumbosacral compression and L4/L5 compression revealed that females had significant main effect of surface for lumbosacral compression (table 28) but not for L4/L5 compression (table 29). The results for males were exactly opposite, i.e., not significant for lumbosacral compression (table 28) but significant of L4/L5 compression (table 29). Their respective multiple comparisons are presented in tables 30 and 31.

The ANOVA tests for the forces generated by muscles as estimated by biomechanical model had mixed results (table 32). The erectores spinae among males did not show any significant main effects, whereas in females both right and left erector spinae had a significant main effect due to the surface ($P<0.001$). Up slope demonstrated least activity (table 33). Similarly, the other dorsal muscle, the latissimus dorsi, also had significant main effect for right muscles in females ($P<0.001$) and left muscle in female ($P<0.001$) but none were significant for males (table 34). Table 35 demonstrates that females seem to have lower force generation in their latissimus dorsi when standing up slope (table 35). Interestingly, the ANOVA for the ventral muscle analysis demonstrated uniform results in males and females where the surface had a significant main effect for rectus abdominis ($P<0.001$) (table 36), internal obliques ($P<0.001$) (table 37), and external obliques ($P<0.002$) (table 38). Their post hoc test for multiple comparison showed that in all cases, the forces generated by the abdominal muscles were lower than those for horizontal or up slope standing (figure 19, tables 39, 40, and 41).

7. DISCUSSION

As it has been stated at length that low back pain is a prevalent and costly problem for the society causing considerable suffering, it will be desirable to develop means to alleviate the cost of this affliction and the human suffering. Our traditional medical system has not had much success in managing this problem. The two primary reasons are that a) we do not understand exact mechanism of causation and perpetuation of the problem and, b) low back pain does not fit the medical model of pathology causing symptomatology. In spite of very active work in the area and truly vast literature, we are still not close to understanding this problem. However, the literature (cited or otherwise) demonstrates that there is a significant association between the mechanical loading of the spine and low back pain. Kumar (2001) made an argument that the human species has evolved over 250 million years under numerous adaptive pressures. The degree of adaptation is extreme and all of it is now genetically coded. Throughout this long period of the evolutionary time none of the activities (which we are required to perform occupationally) were needed or performed. It is, therefore, apparent that the humans are trying to fight nature to reverse its course. Furthermore, the manner in which nature works is not allowed to take its course due to our advanced civilization. Therefore, of necessity, we are required to adapt best we can within our lifetime leaving no genetic imprint of such adaptation. Additionally, these adaptations are likely more driven by our attitudinal choice rather than better biological fit. Taking these factors into account, along side the mode of nature's operation, it is obvious that our musculoskeletal disorders (among them back pain is foremost) is here to stay until the society reverses its course from industrial to primitive values. This presents us a challenge as to how we deal with this issue and or cope with the problem which is an outcome of a lifestyle of our choosing.

With respect to postural aberrations in low back pain, Christie, Kumar and Warren (1995) reported discrete postural profiles for chronic, acute pain, and control groups. The authors stated that the chronic pain patients exhibited exaggerated lumbar lordosis and acute pain patients demonstrated increased thoracic kyphosis, as compared to control groups. The authors emphasized that the postural parameters are significantly different in chronic low back pain in comparison to controls. However, they could not state whether the poor posture leads to low back pain or if it is an adaptation to pain. However, it was speculated that both scenarios were possible. Thus, unless clearly delineated it can be a vicious circle. Evecik and Yucel (2003) also reported that the sacral inclination angle was significantly higher and correlated with lumbar extension in chronic low back patients ($P<0.05$). Chronic low back pain also restricts the maximum range of lumbar extension.

Scannel and McGill (2003) studied six hypolordotic, six hyperlordic and six control spines with respect to their posture. They measured the lumbar passive tissue stiffness during sitting, standing and walking before and after 12 week exercise program and estimates of passive tissue strain. The authors reported that after the exercise program completion, both hypo- and hyperlordotic subjects stood within their neutral zones. With training both groups migrated towards a mean posture which was demonstrated by the controls. The authors argued that the tissue failures can be related to tissue strains, and the results supported the practice of attempting to correct the posture. Though not stated, the implication may be that it will help alleviate the low back pain problem.

Occupational low back pain problem is not confined to the developed world. Omokhodion and Sanya (2003) conducted a cross sectional study in Ibadan, Nigeria using a questionnaire survey of civil service. With a response rate of 66% the authors reported that the 12 month prevalence of low back pain was 38% and the point prevalence was 20%. They found that the low back pain was associated with seniority and sitting for more than three hours.

Thus if the low back pain is collar blind (affects both blue collar and white collar workers) and neutral to affluence of the society (both developed and developing world), it spares no one. The current micro-computer revolution and the information/knowledge based economy are transforming the work such that more and more people are interacting with their computers to perform their occupational activities. Therefore, it would appear logical to revolutionize the work station which will be more compatible to the biological system and will allow change of posture, frequently, to alleviate risks associated with sedentary work.

The Delta Balance Standing Platform (DBSP) was developed to address these issues. The extensive study reported here has tried to tease out some of the tangibles which affect people while working on DBSP. One must point out here that for occupations to be carried out in upright standing the resting posture is the base line which represents a minima, or no activity.

As discovered in this study these standing postures were associated with extremely low level activities. The painstaking meticulous work and different iterations of EMG data analysis did not yield conclusive and convincing results. At times, opposite trends were seen between two genders. This is clearly understandable given differences in body structure of the two genders. Generally, males have wider chests, and females have additional weight in the front due to their breasts. Females normally have larger pelvis compared to their male counterparts. Therefore, minor differences found in EMG data could not allow us to conclude definitively the value of platform with respect to the muscle loads. However, it must be pointed out that no matter however comfortable, no "one" posture can be designated as the correct posture. A range of postures are significantly better than a single posture. In this sense, the DBSP technology provides advanced beneficial features not yet included in other systems. However, it is also recommended that an addition of sitting device coupled with DBSP will further enhance its health value to the users.

Some of the specific findings include that peak erectores spinae EMG scores were lowest in down slope and highest in horizontal. The average values showed a 6% MVC score in down slope and 17% up slope at L3 level. Generally, for static and pronged activities the average valves are thought to be more meaningful as they represent the overall load. While standing down slope (or up slope) on a 15° inclination, the area of support under feet undergoes a reduction due to 4% shortening ($d2 = d \times \cos(\theta)$; $\theta = 15^{o}$) of the length covered by the feet. Due to this change in down slope standing, the individual will have to slightly tilt backwards. Such an adjustment will have a function of bringing the centre of mass, of the individual, closer to the geometric centre of the lumbar spine and reducing its length of the lever arm, hence the torque. Essentially then, it will reduce the torque required to maintain a balance reducing the load on spine. Though such changes appear small, but when considered that they will be operative for the entire work day, work week and work year, they are considerable. The cumulative load reduction can become significant and will have a positive effect on the user. In up slope posture the tilt is going to be forward and a similar logic will apply.

However, to maintain the postural equilibrium the gastrocnemii and hamstrings will play a major role and the spinal muscles will be demanded less due to the reduction of the area of support and reducing spinal compression load. In spite of insignificant findings, through the analysis of variance, it needs to pointed out that we were comparing small differences from a very small sample of subjects. For such studies of upward of 20 subjects for each gender will be minimal sample size to begin to discern significant differences. However, given the limitations of this project (including financial) the trends observed are encouraging.

In frequency domain analysis a significant difference between genders and different surfaces are interesting. The MF and MPF for males were lower for the down slope compared to up slope implying generally a lower level activity of the muscles. It can be implied that the down slope provided a more passively balanced posture for men. In females, on the other hand, the MF and MPF were lowest in horizontal position. Perhaps, the natural balance among females may be different due to breasts in front and buttocks at the back. Lack of significance in total and peak power may indicate that these activities involved only low level recruitment of muscles.

It is for these very reasons, that we observed, that the spinal compression was lowest in down slope for men and horizontal for women. The divergence between males and females with respect to force generated by dorsal muscles (erectores spinae) is again a reflection of difference in gender anatomy and how they get influenced by slopes. In up slope the females demonstrated the least force whereas the males generated the most. And, for down slope the males generated lower values than females. This likely was affected by the mass distribution on body. The lumbosacral compressions were of very low values with some inconsistent patterns. It may be that they were more the function of individual torso masses as compared to the surfaces. These values were close to torso masses.

8. Conclusions

i) The results obtained for all conditions were of very low magnitude due to the nature of the activity (quiet standing).

ii) The nature of results obtained do not allow to derive strong and emphatic conclusions.

iii) The results demonstrate a trend that down slope inclination was biomechanically less stressful for men for not for women.

iv) The results suggest that up slope standing for females was biomechanically more advantageous than down slope.

v) However, the horizontal slope in many cases was close to either down slope or up slope.

vi) It would be desirable to provide option for use of both up- and down slope surfaces and not to outrule the horizontal.

vii) It will also be desirable to add a seating device to the work station to provide further variation of posture possible.

viii) For more convincing results, larger number of subjects and more rigid experimental protocol will be needed.

ix) It will be worthwhile to launch a clinical study to determine degree, nature and time required for relief.

9. References

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Figure 1. Deltabalance balance standing platform

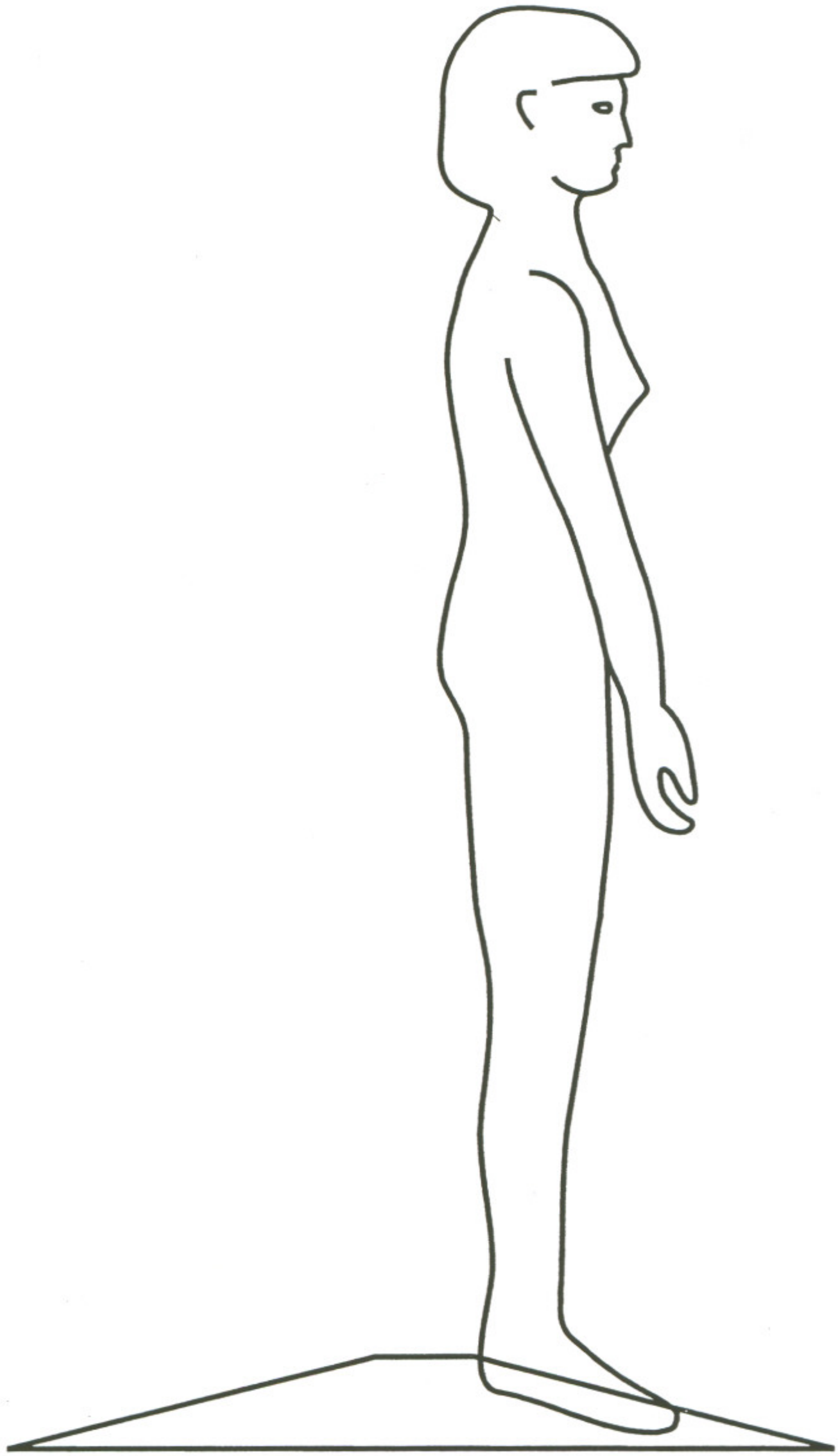
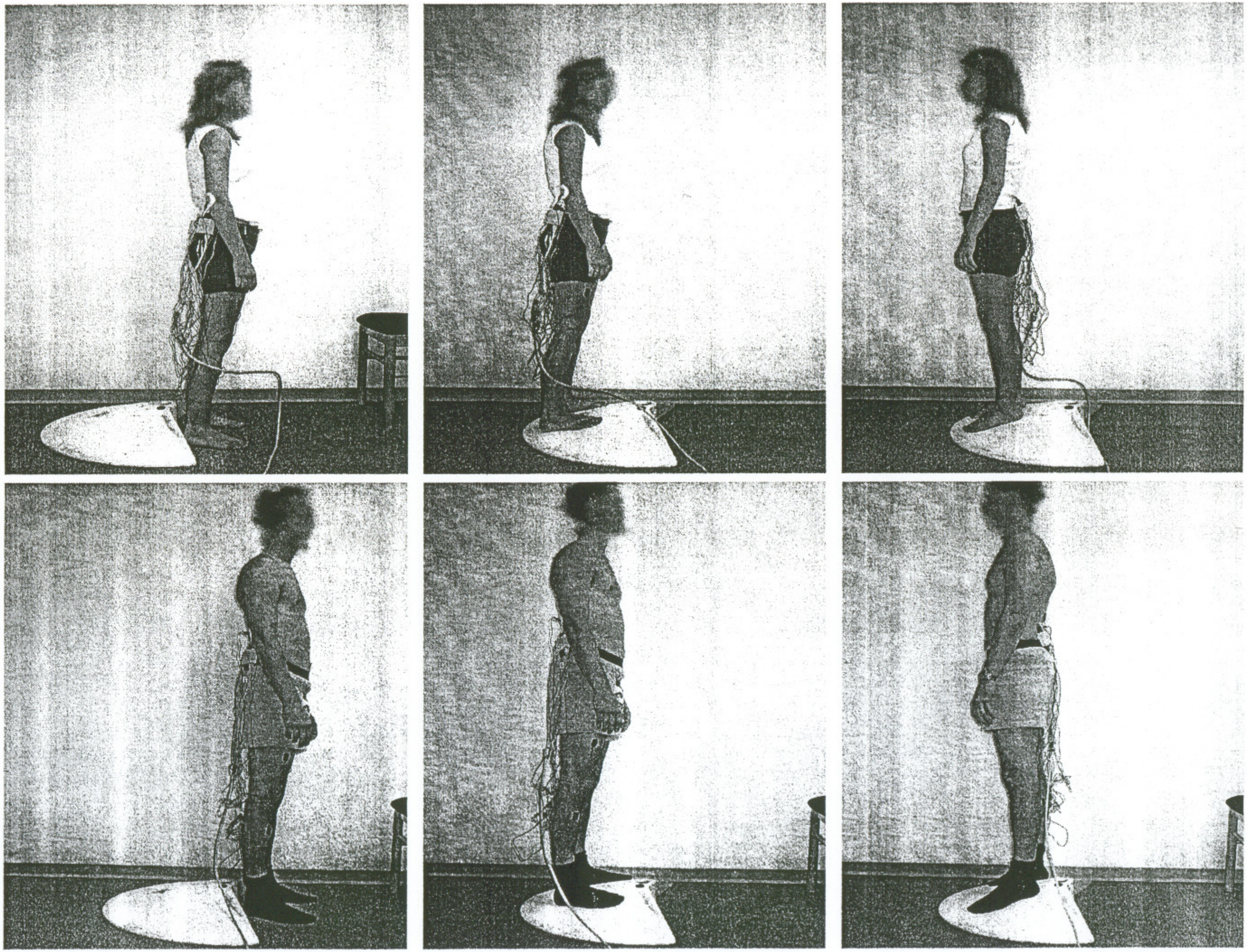


Figure 2. Subjects standing on experimental surfaces.



Horizontal Up-Slope Down-Slope

Figure 3. Toe stand.

Figure 4. Heel stand.

Figure 5. Trunk extension.

Figure 6. EMG Analysis procedures.

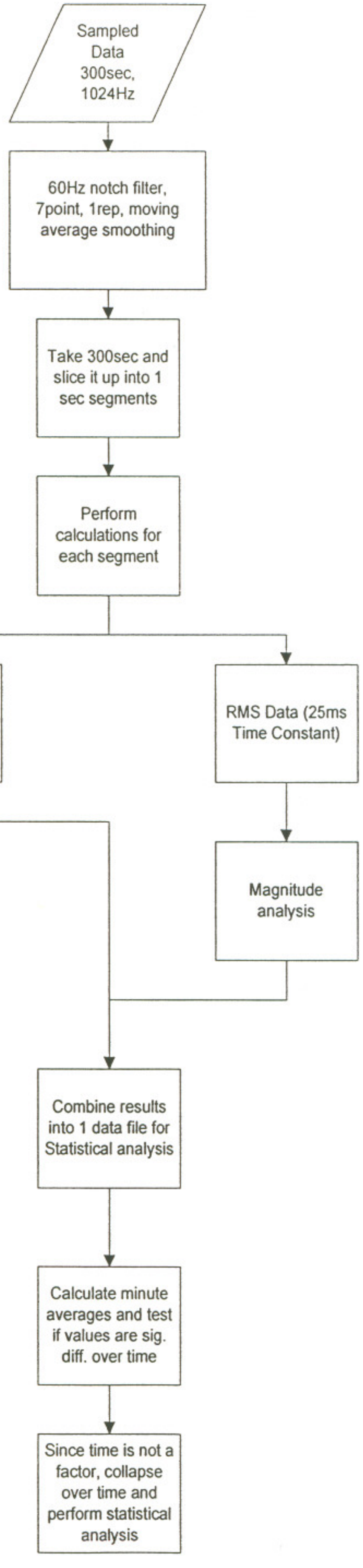


Figure 7. Posture, spinal load analysis with Biomechanical Model.

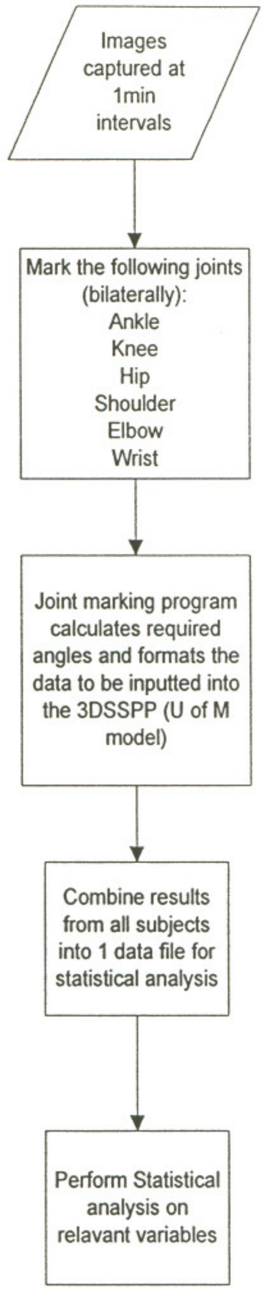


Figure 8. Normalized peak and average EMG activity during standing on three surfaces.

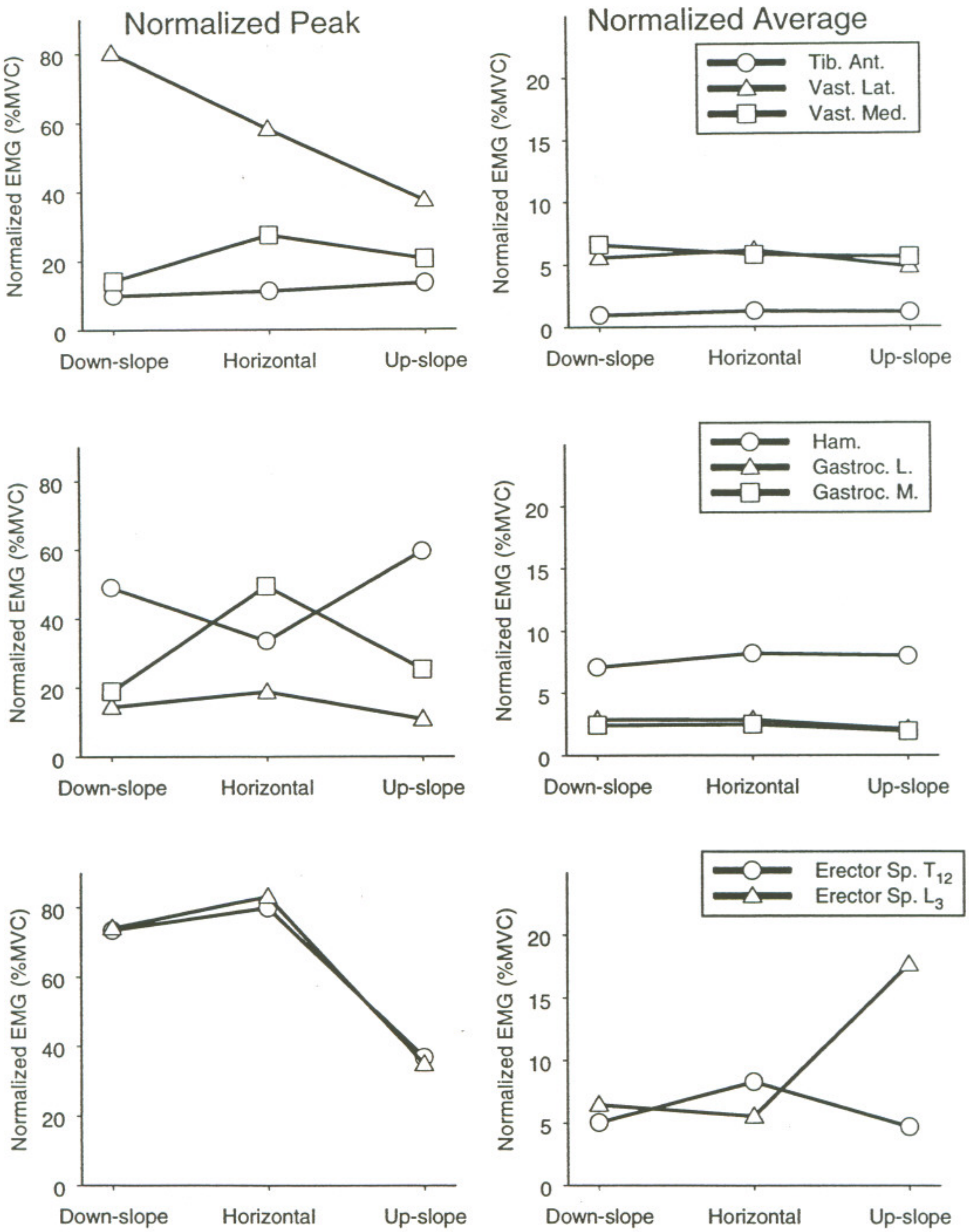


Figure 9. Horizontal and up-slope mean average EMG values normalized against the down slope values (%).

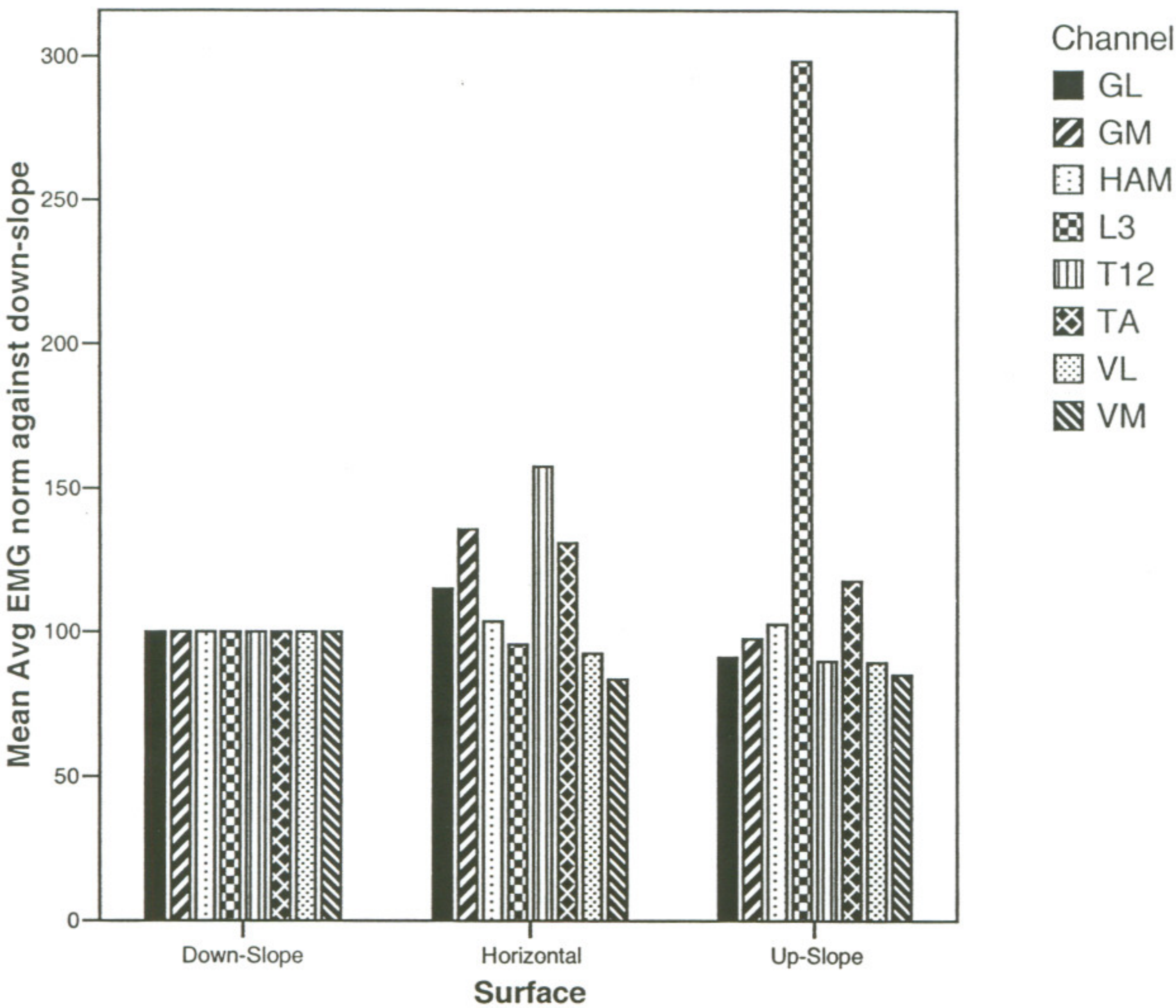


Figure 10. Horizontal and up-slope mean peak EMG values normalized against the down slope values (%).

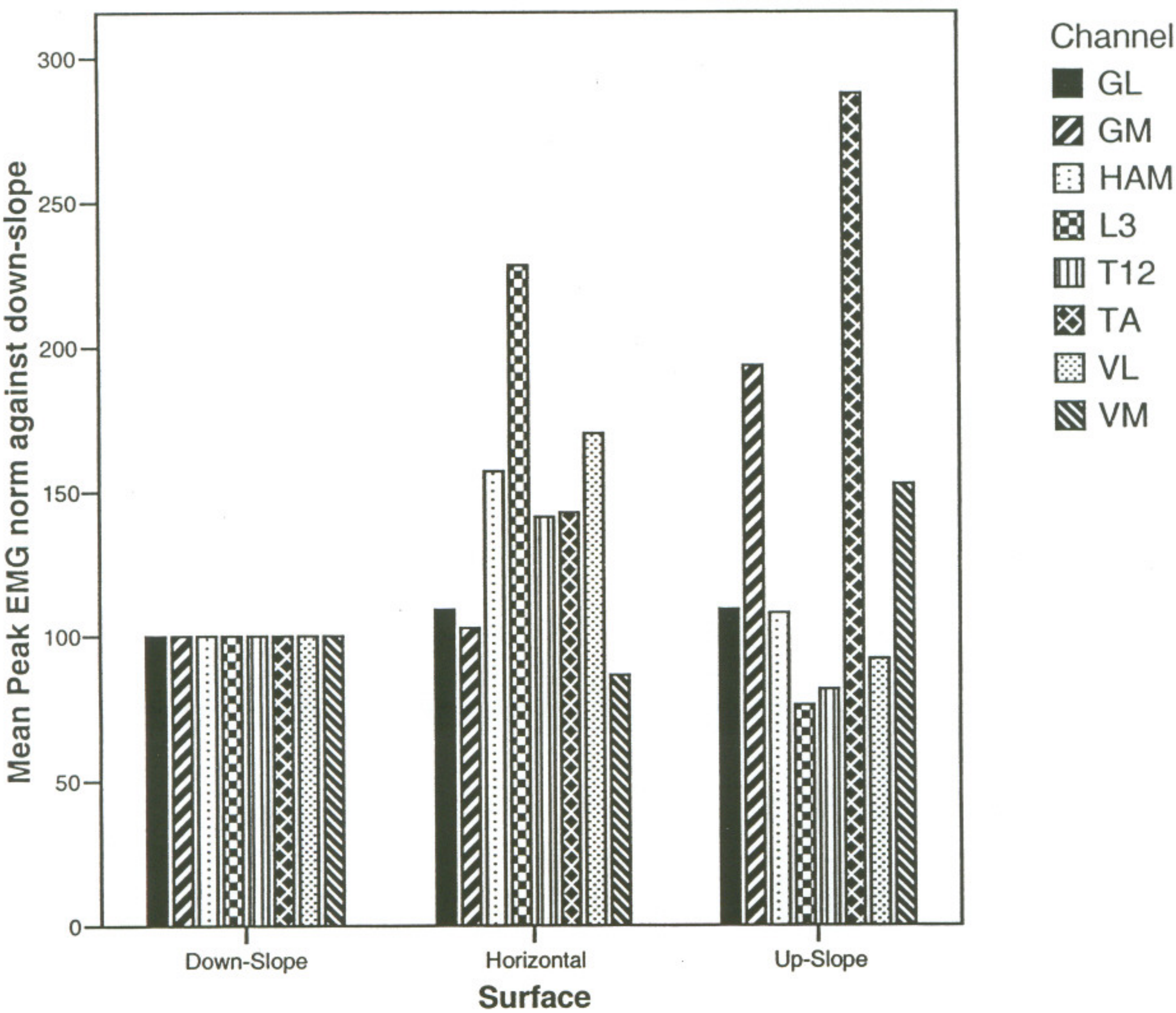


Figure 11. The mean median frequency for different muscles for two genders while standing on three surfaces.

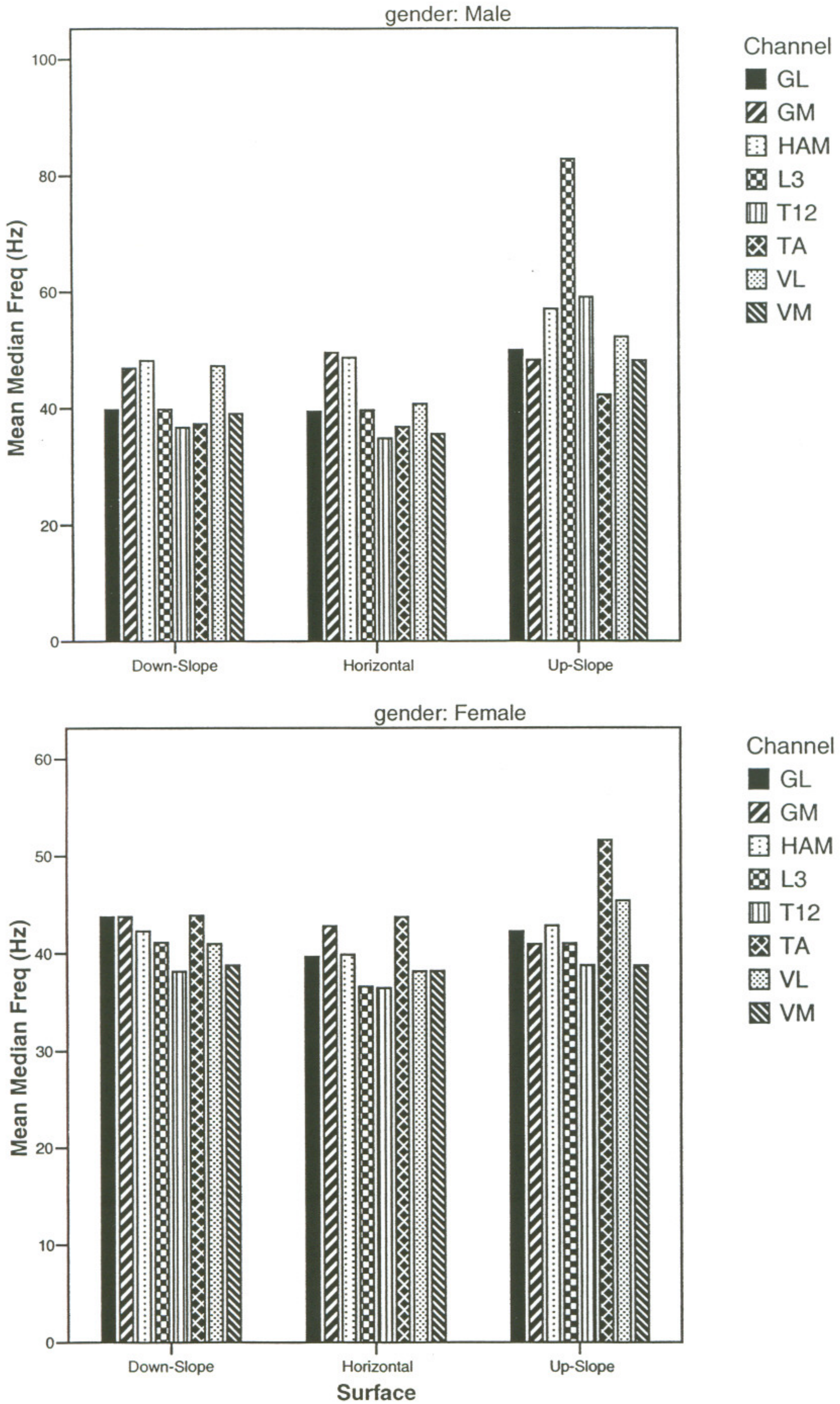


Figure 12. The mean mean power frequency for different muscles for two genders while standing on three surfaces.

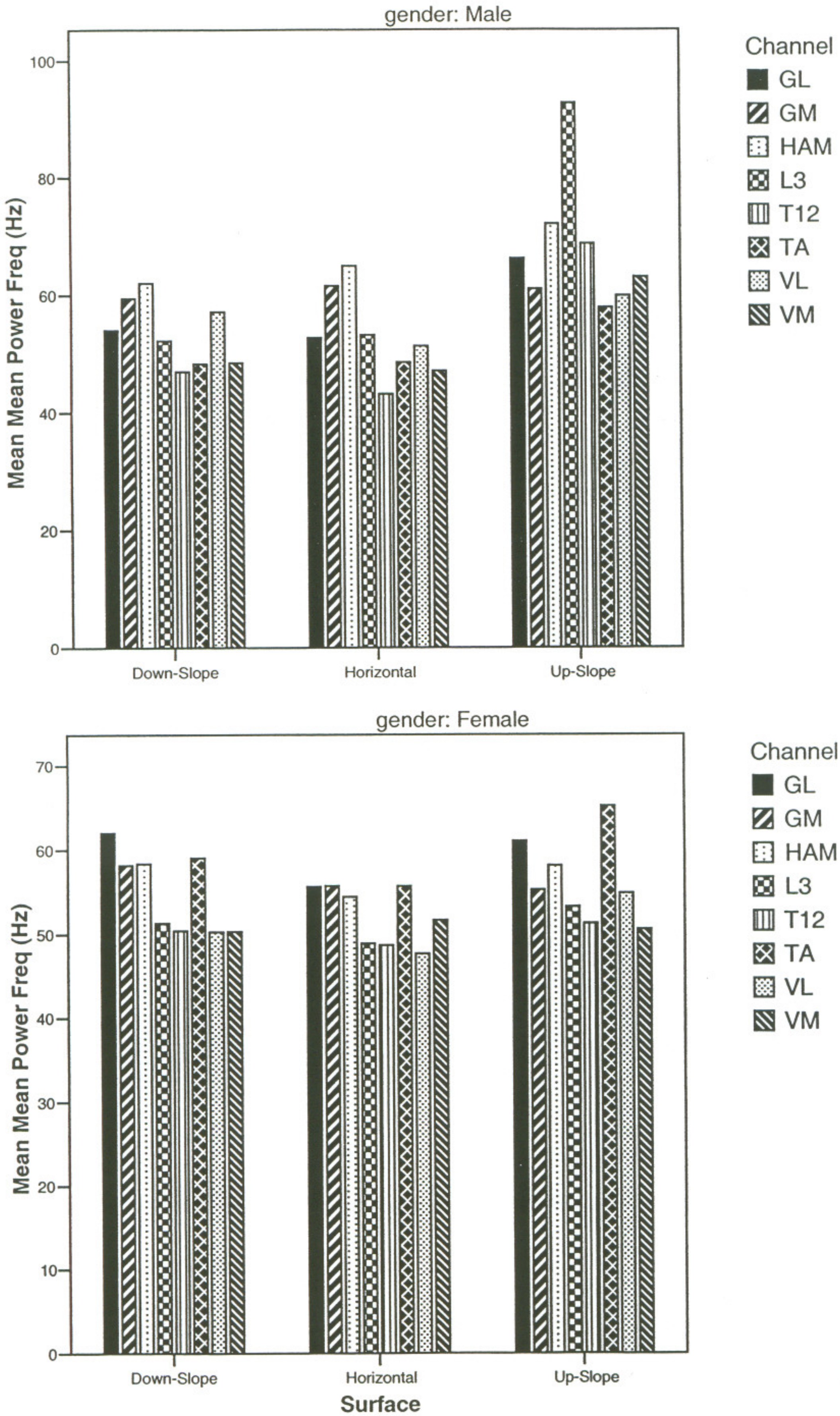


Figure 13. Median frequency and mean power frequency normalized against the down slope (%).

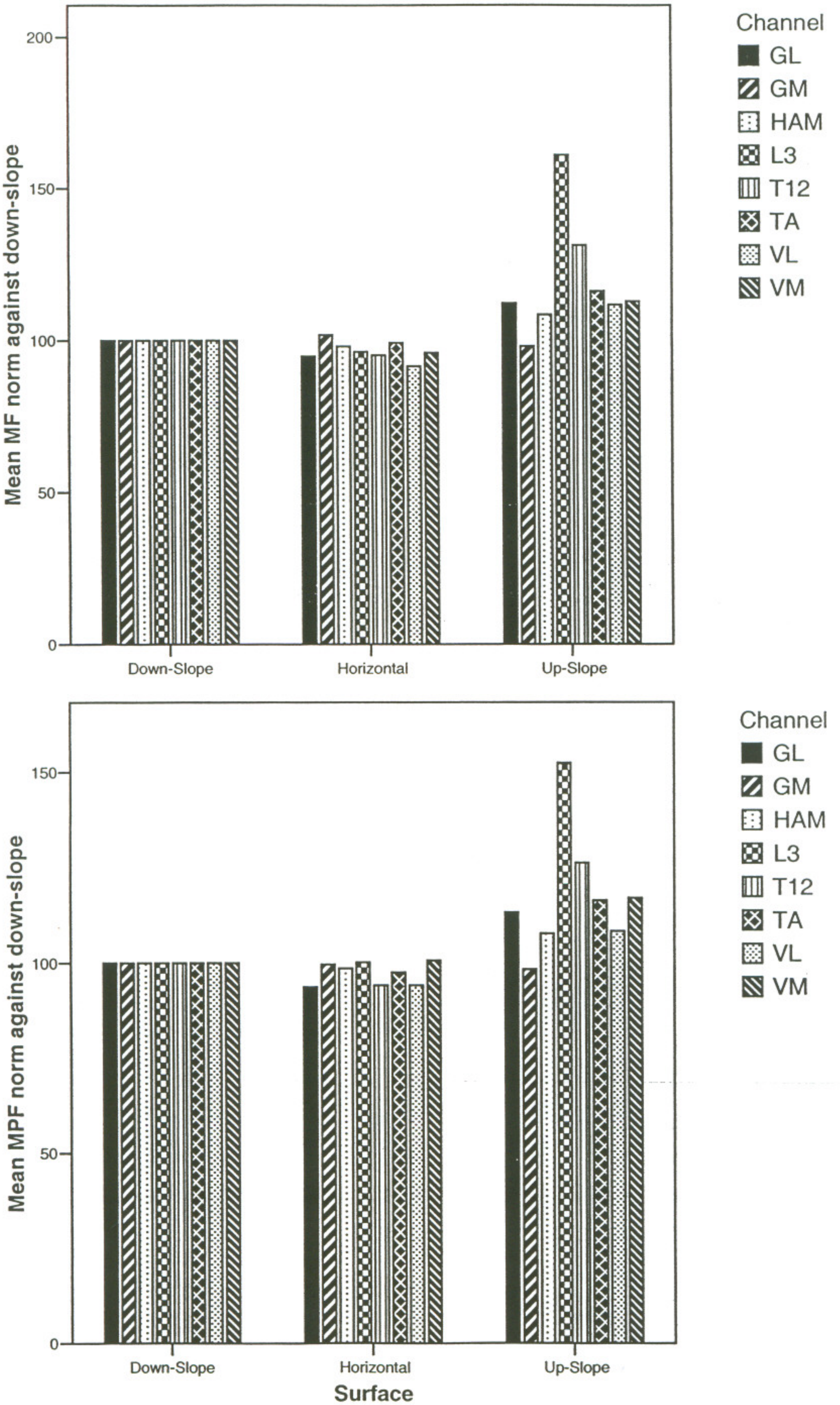


Figure 14. Total power and peak power of muscles normalized against the down slope (%).

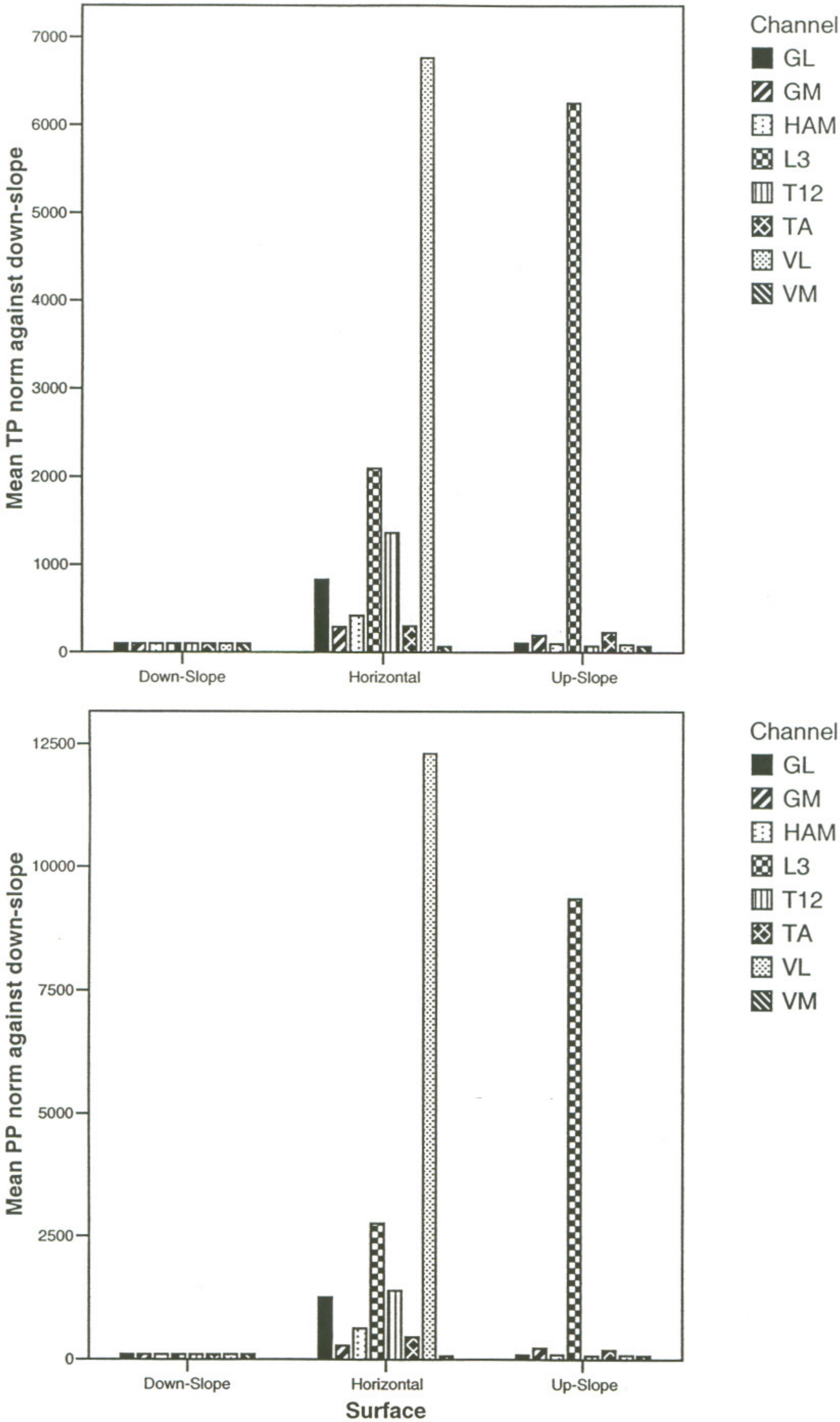
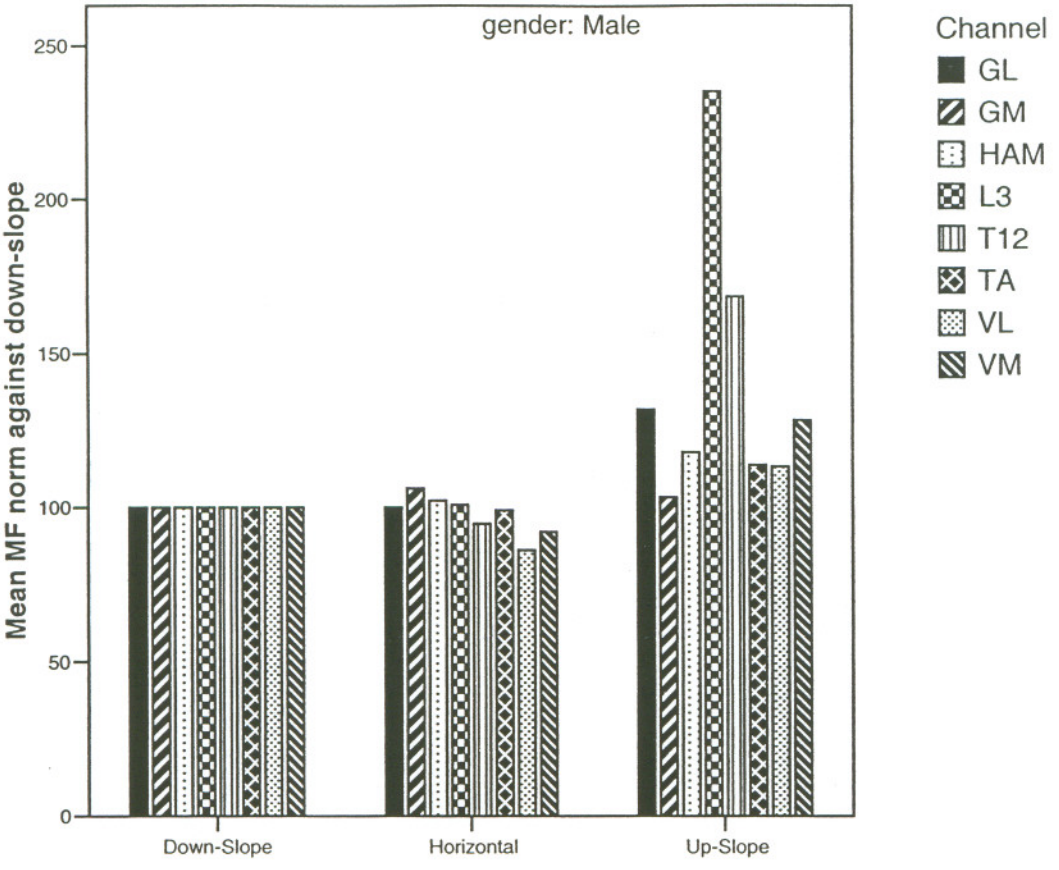


Figure 15. Mean median frequency for male and female samples normalized against down slope (%).



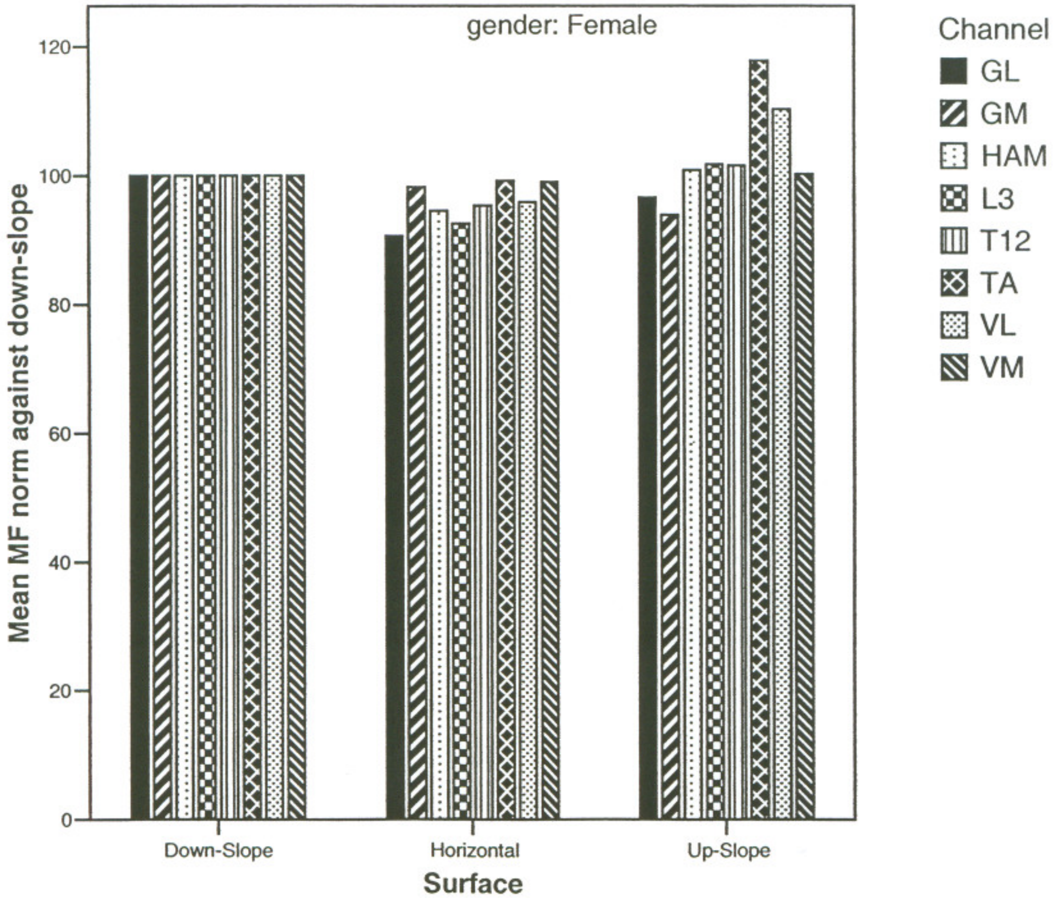


Figure 16. Mean mean power frequency for male and female samples normalized against down slope (%).

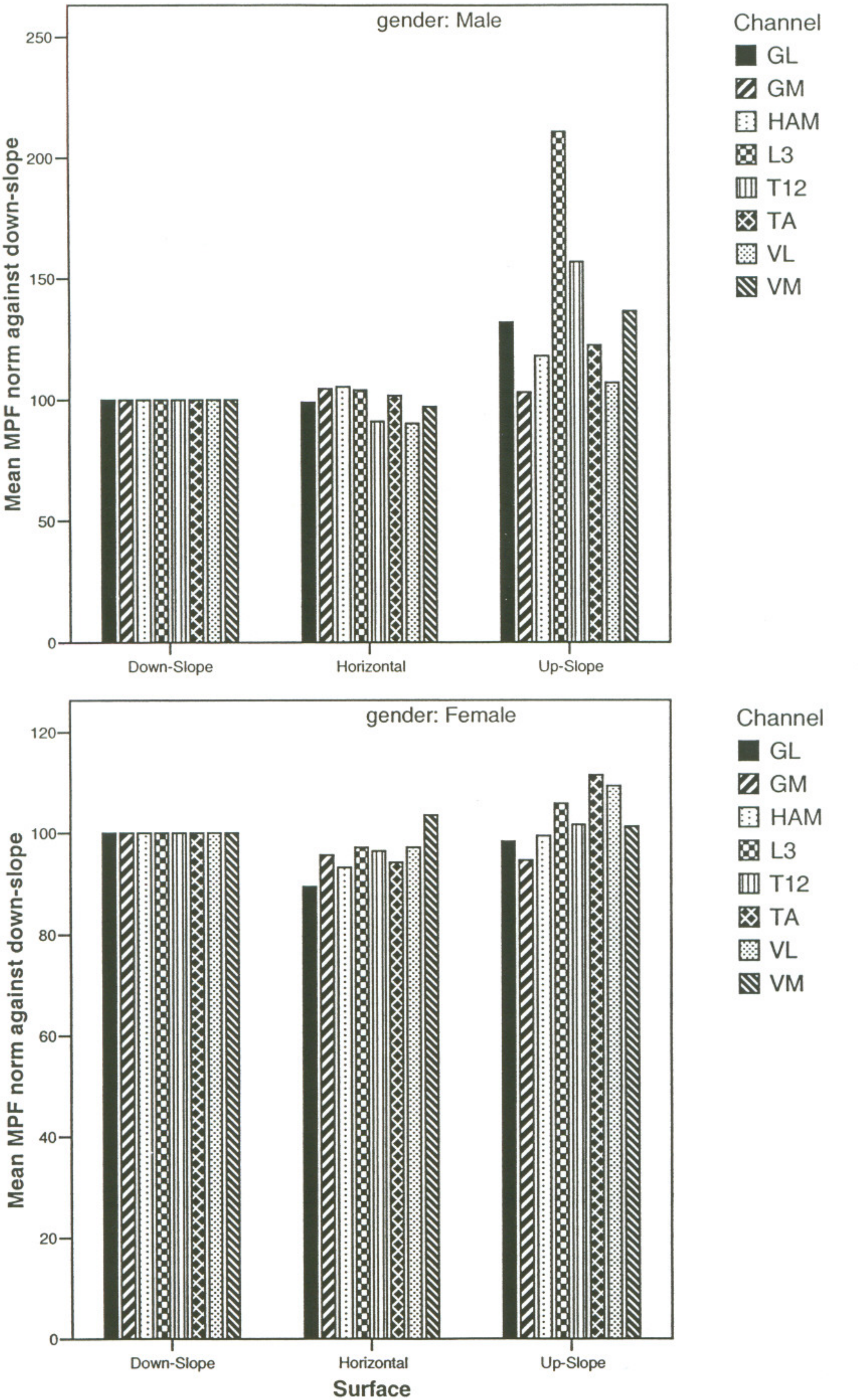


Figure 17. Spinal compression and shear among male and female subjects while standing on three surfaces.

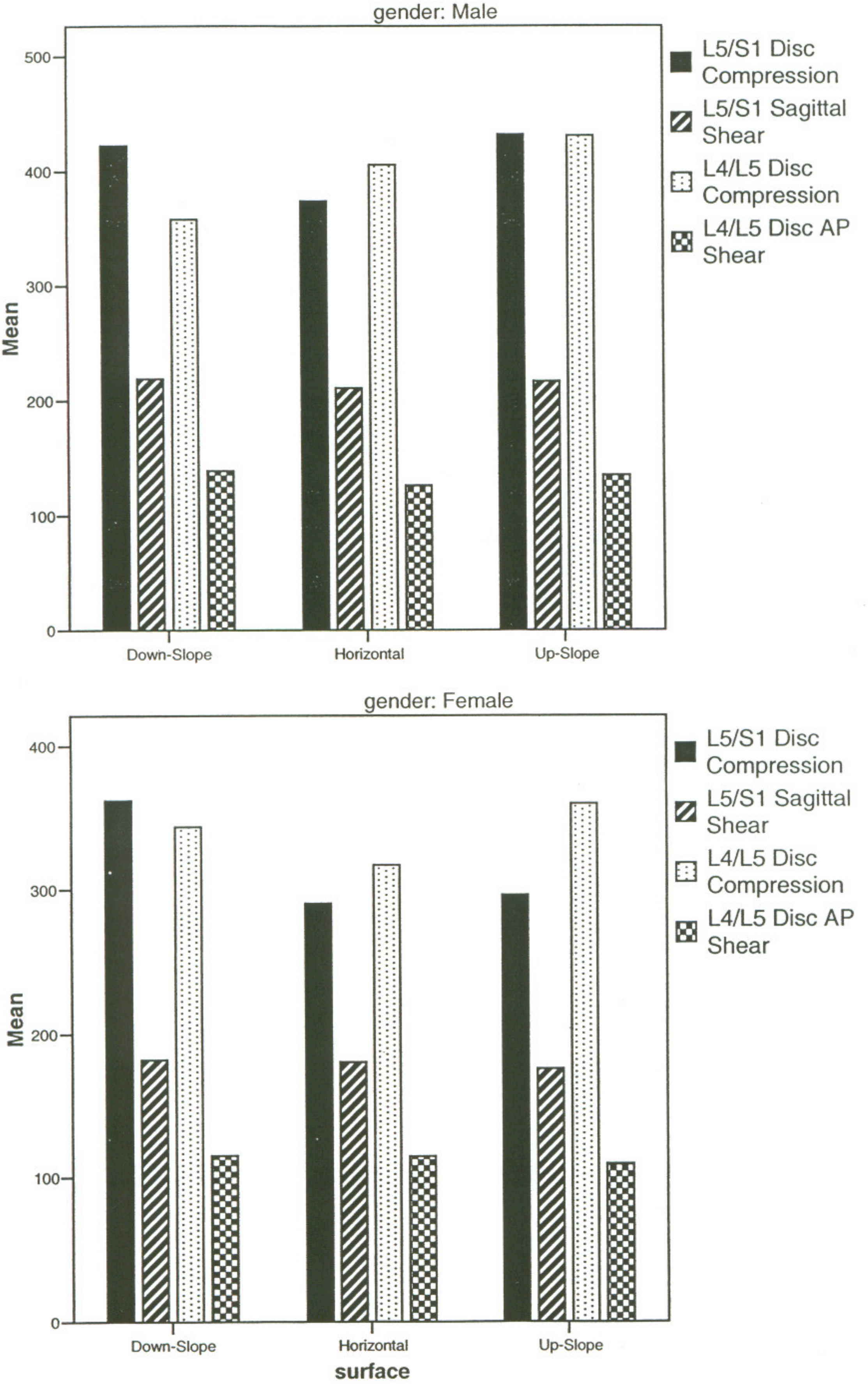


Figure 18. Forces generated by dorsal muscles.

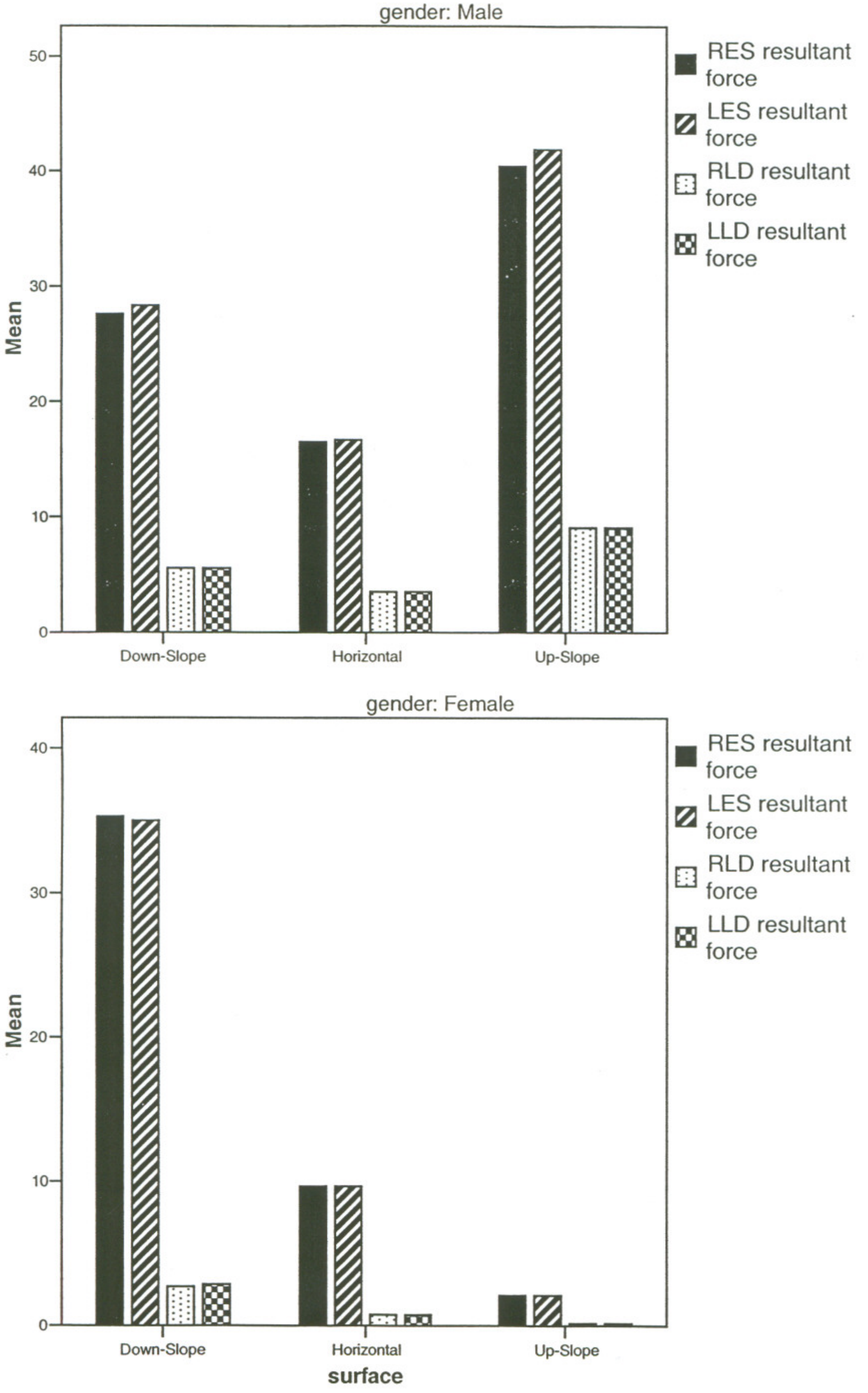


Figure 19. Forces generated by ventral muscles.

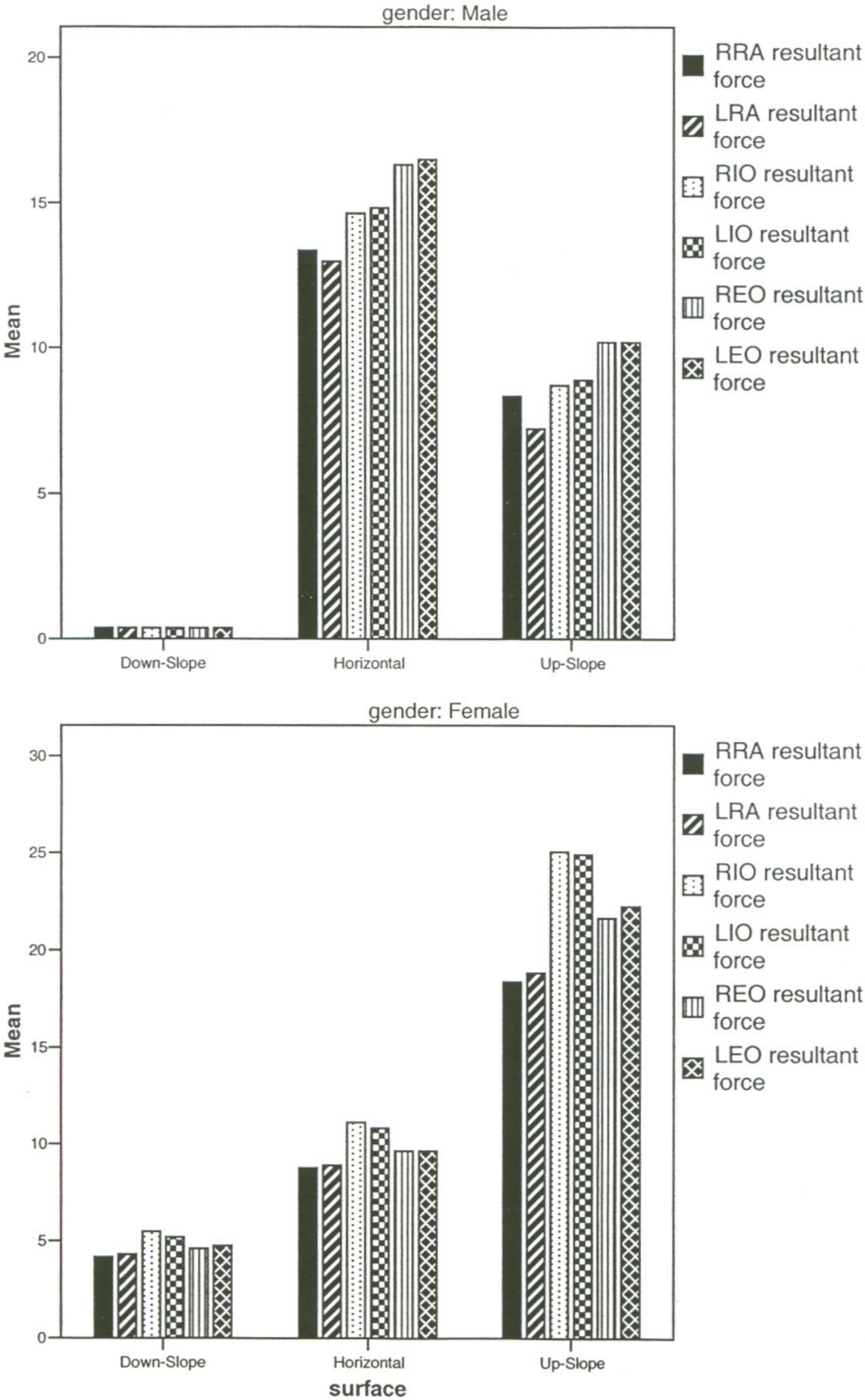


Table 1. Anthropometric data of sample subject.

				Age	Height (cm)	Weight (kg)
Male	M1	Handedness	Left	38	185	113
	M2	Handedness	Right	32	183	75
	M3	Handedness	Right	34	172.7	77
	M4	Handedness	Right	20	178	68
	M5	Handedness	Right	20	167.6	77
Female	F1	Handedness	Right	32	157	73.5
	F2	Handedness	Right	23	162.6	50
	F3	Handedness	Right	29	171.5	66
	F4	Handedness	Right	31	177.8	70.8
	F5	Handedness	Right	21	160	52

Gender means and standard deviations

	Age		Height (cm)		Weight (kg)	
	Mean	**Std Deviation**	**Mean**	**Std Deviation**	**Mean**	**Std Deviation**
Male	28.8	8.3	177.3	7.2	82.0	17.7
Female	27.2	4.9	165.8	8.6	62.5	10.8

Sample means and standard deviations

Age		Height (cm)		Weight (kg)	
Mean	**Std Deviation**	**Mean**	**Std Deviation**	**Mean**	**Std Deviation**
28.0	6.5	171.5	9.6	72.2	17.3

Table 2. The peak and average EMG while standing on three surfaces (μV).

		Surface											
		Down-Slope				Horizontal				Up-Slope			
		Peak EMG (microV)		Avg EMG (microV)		Peak EMG (microV)		Avg EMG (microV)		Peak EMG (microV)		Avg EMG (microV)	
		Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
Channel	GL	10.74	6.72	2.02	1.65	8.78	5.65	1.92	.74	10.70	10.05	1.55	.78
	GM	21.94	19.50	3.19	3.14	104.20	230.70	3.41	2.69	27.18	21.90	2.43	1.43
	HAM	25.93	43.70	1.52	.85	15.95	11.93	1.43	.45	10.99	9.02	1.37	.38
	L3	20.78	22.27	2.72	2.22	38.33	39.85	1.90	.39	9.16	4.33	9.63	23.91
	T12	25.61	32.10	2.00	.62	23.88	31.60	3.60	4.88	10.77	5.62	1.72	.71
	TA	18.08	13.22	2.07	.85	31.91	43.89	2.45	1.22	29.03	17.43	2.27	1.41
	VL	17.32	13.12	3.55	2.24	38.04	49.09	2.41	.59	12.47	5.11	2.48	1.10
	VM	8.50	3.42	2.53	1.41	9.45	7.74	1.91	.82	14.24	16.71	1.87	.48

Table 3. The normalized peak and average EMG while standing on three experimental surfaces (%MVC)

		Surface											
		Down-Slope				Horizontal				Up-Slope			
		Norm Peak (%)		Norm Avg (%)		Norm Peak (%)		Norm Avg (%)		Norm Peak (%)		Norm Avg (%)	
		Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
Channel	GL	14.36	13.05	2.87	2.60	18.74	24.66	2.86	2.45	10.82	5.21	2.11	1.37
	GM	18.91	20.34	2.43	1.42	49.42	104.36	2.48	.79	25.22	36.42	1.93	.83
	HAM	49.04	69.85	7.06	6.15	33.54	22.62	8.17	9.18	59.49	91.55	7.96	10.10
	L3	74.11	129.01	6.46	5.95	83.12	97.91	5.54	5.39	34.97	56.18	17.68	39.51
	T12	73.48	113.51	5.04	3.44	79.92	146.63	8.29	8.85	36.86	43.39	4.71	3.96
	TA	9.99	9.00	.97	.64	11.27	12.49	1.29	1.07	13.56	9.39	1.18	1.08
	VL	80.18	137.87	5.56	3.89	58.23	77.31	6.13	7.10	37.31	58.58	4.80	3.80
	VM	14.22	7.37	6.61	5.65	27.38	41.89	5.76	5.60	20.42	11.88	5.58	5.14

Table 4. Average and peak EMG values normalized against down slope.

		Surface											
		Down-Slope				Horizontal				Up-Slope			
		Avg EMG norm against down-slope		Peak EMG norm against down-slope		Avg EMG norm against down-slope		Peak EMG norm against down-slope		Avg EMG norm against down-slope		Peak EMG norm against down-slope	
		Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
Channel	GL	100.00	.00	100.00	.00	115.02	42.94	109.06	25.37	91.14	29.12	108.99	91.84
	GM	100.00	.00	100.00	.00	135.70	102.20	102.66	55.13	97.53	47.75	193.51	239.07
	HAM	100.00	.00	100.00	.00	103.54	32.04	157.12	129.53	102.60	36.46	107.70	82.21
	L3	100.00	.00	100.00	.00	95.53	50.93	228.17	302.11	298.36	635.04	75.97	25.06
	T12	100.00	.00	100.00	.00	157.59	155.69	141.17	37.67	89.85	28.03	81.37	39.21
	TA	100.00	.00	100.00	.00	130.97	82.48	142.75	154.93	117.78	59.43	287.57	404.25
	VL	100.00	.00	100.00	.00	92.53	53.96	170.18	101.42	89.42	43.55	92.05	35.58
	VM	100.00	.00	100.00	.00	83.53	26.01	86.36	34.87	85.14	24.92	152.37	141.00

Table 5. ANOVA summary table for mean peak EMG (μV).

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	123083.258[a]	47	2618.793	1.011	.468
Intercept	81858.602	1	81858.602	31.588	.000
gender	5138.222	1	5138.222	1.983	.161
surface	8733.250	2	4366.625	1.685	.189
chanx	20913.844	7	2987.692	1.153	.334
gender * surface	2095.394	2	1047.697	.404	.668
gender * chanx	18849.857	7	2692.837	1.039	.407
surface * chanx	21194.213	14	1513.872	.584	.874
gender * surface * chanx	36452.677	14	2603.763	1.005	.453
Error	336884.320	130	2591.418		
Total	549581.270	178			
Corrected Total	459967.578	177			

a. R Squared = .268 (Adjusted R Squared = .003)

Table 6. ANOVA summary table for mean average EMG (μV).

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1352.197[a]	47	28.770	1.120	.296
Intercept	1500.450	1	1500.450	58.435	.000
gender	85.304	1	85.304	3.322	.070
surface	16.664	2	8.332	.324	.723
chanx	229.098	7	32.728	1.275	.266
gender * surface	30.078	2	15.039	.586	.558
gender * chanx	181.402	7	25.915	1.009	.427
surface * chanx	440.234	14	31.445	1.225	.262
gender * surface * chanx	502.170	14	35.869	1.397	.159
Error	4313.766	168	25.677		
Total	7105.738	216			
Corrected Total	5665.963	215			

a. R Squared = .239 (Adjusted R Squared = .026)

Table 7. ANOVA summary table for the mean peak EMG magnitude when normalized against down-slope values.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	774726.870[a]	47	16483.550	.830	.761
Intercept	2429139.876	1	2429139.876	122.268	.000
gender	730.678	1	730.678	.037	.848
surface	64134.161	2	32067.081	1.614	.204
chanx	101050.190	7	14435.741	.727	.650
gender * surface	11789.143	2	5894.571	.297	.744
gender * chanx	124990.862	7	17855.837	.899	.510
surface * chanx	329600.871	14	23542.919	1.185	.297
gender * surface * chanx	197911.090	14	14136.506	.712	.759
Error	2145664.855	108	19867.267		
Total	5425630.401	156			
Corrected Total	2920391.725	155			

a. R Squared = .265 (Adjusted R Squared = -.054)

Table 8. ANOVA summary table for the mean average EMG magnitude when normalized against down-slope values.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	979835.837[a]	47	20847.571	1.120	.297
Intercept	2697622.201	1	2697622.201	144.921	.000
gender	4745.742	1	4745.742	.255	.614
surface	20509.238	2	10254.619	.551	.577
chanx	132650.374	7	18950.053	1.018	.420
gender * surface	35597.956	2	17798.978	.956	.386
gender * chanx	193363.966	7	27623.424	1.484	.176
surface * chanx	332304.495	14	23736.035	1.275	.227
gender * surface * chanx	359915.672	14	25708.262	1.381	.167
Error	3127232.631	168	18614.480		
Total	6813012.217	216			
Corrected Total	4107068.467	215			

a. R Squared = .239 (Adjusted R Squared = .026)

Table 9. The median and mean power frequencies of 8 muscles while standing on three surfaces.

			Surface											
			Down-Slope				Horizontal				Up-Slope			
			Median Freq (Hz)		Mean Power Freq (Hz)		Median Freq (Hz)		Mean Power Freq (Hz)		Median Freq (Hz)		Mean Power Freq (Hz)	
			Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
Male	Channel	GL	39.78	7.30	54.03	14.31	39.41	4.92	52.74	10.77	49.93	9.85	66.18	7.35
		GM	46.89	7.61	59.44	9.11	49.54	13.02	61.53	10.27	48.25	8.55	60.99	8.28
		HAM	48.16	9.20	61.98	10.88	48.69	10.62	64.94	10.81	57.04	17.50	72.06	16.12
		L3	39.81	6.84	52.22	11.96	39.68	3.15	53.20	7.61	82.76	87.46	92.71	80.01
		T12	36.72	6.17	46.99	9.25	34.85	6.61	43.15	11.17	59.10	43.27	68.71	41.47
		TA	37.31	3.37	48.30	8.09	36.83	2.70	48.60	6.28	42.27	6.48	57.83	11.90
		VL	47.27	7.48	57.14	6.56	40.70	8.12	51.31	7.46	52.23	19.21	59.84	16.90
		VM	39.07	6.15	48.49	6.21	35.58	2.14	47.09	6.87	48.18	20.57	63.01	27.80
Female	Channel	GL	43.73	2.02	62.01	4.00	39.65	4.28	55.60	9.56	42.22	2.15	61.00	5.53
		GM	43.76	7.82	58.19	8.31	42.76	9.24	55.70	9.70	40.89	6.18	55.20	9.33
		HAM	42.27	3.65	58.35	5.24	39.85	4.53	54.41	8.29	42.79	7.50	58.10	7.49
		L3	41.11	12.18	51.34	11.99	36.58	3.59	48.88	7.43	40.98	8.70	53.19	9.06
		T12	38.17	1.90	50.41	3.34	36.41	2.03	48.66	4.22	38.74	3.28	51.23	4.78
		TA	43.86	5.44	59.04	7.01	43.69	8.79	55.68	8.64	51.59	11.31	65.17	7.28
		VL	40.96	7.85	50.26	9.69	38.15	6.96	47.66	9.13	45.37	11.49	54.82	11.02
		VM	38.80	4.41	50.29	7.03	38.20	2.85	51.63	5.07	38.73	3.51	50.53	5.43

Table 10. Total power and peak power of 8 muscles studied during standing on three surfaces.

		Surface											
		Down-Slope				Horizontal				Up-Slope			
		Total Power (microV^^2)		Peak Power (microV^^2/Hz)		Total Power (microV^^2)		Peak Power (microV^^2/Hz)		Total Power (microV^^2)		Peak Power (microV^^2/Hz)	
		Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
Channel	GL	164.57	489.28	14.23	42.40	44.79	98.81	3.53	7.56	2.49	4.45	.13	.20
	GM	217.57	641.56	18.14	53.76	17.58	25.01	1.06	1.39	9.54	12.49	.68	1.11
	HAM	26.82	76.34	2.26	6.51	4.27	8.09	.32	.65	1.22	.70	.07	.05
	L3	229.25	678.37	20.27	60.16	18.54	47.69	1.67	4.43	694.93	2079.71	82.81	248.10
	T12	5.10	6.73	.40	.53	85.65	244.76	7.98	22.94	2.03	1.73	.14	.13
	TA	16.53	40.93	1.03	2.60	10.72	16.87	.85	1.59	5.59	6.64	.27	.29
	VL	276.25	758.81	25.40	68.96	96.46	264.08	9.98	27.97	4.39	3.36	.25	.18
	VM	132.08	384.06	11.02	32.19	5.04	9.26	.40	.78	2.32	1.24	.16	.10

Table 11a. Median and mean power frequencies normalized against down-slope.

		Surface											
		Down-Slope				Horizontal				Up-Slope			
		MF norm against down-slope		MPF norm against down-slope		MF norm against down-slope		MPF norm against down-slope		MF norm against down-slope		MPF norm against down-slope	
		Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
Channel	GL	100.00	.00	100.00	.00	94.77	9.17	93.64	11.53	112.26	34.86	113.27	34.37
	GM	100.00	.00	100.00	.00	101.80	20.22	99.60	14.08	98.08	10.76	98.38	8.77
	HAM	100.00	.00	100.00	.00	98.01	15.77	98.62	13.28	108.40	20.56	107.70	21.92
	L3	100.00	.00	100.00	.00	96.29	13.90	100.22	13.99	161.01	187.69	152.46	154.85
	T12	100.00	.00	100.00	.00	95.07	2.19	94.09	5.44	131.29	92.25	126.20	79.30
	TA	100.00	.00	100.00	.00	99.14	9.83	97.57	11.33	116.07	20.43	116.34	25.69
	VL	100.00	.00	100.00	.00	91.55	18.73	94.08	18.63	111.65	32.92	108.31	25.74
	VM	100.00	.00	100.00	.00	95.92	8.41	100.69	9.18	112.76	45.46	117.00	53.55

Table 11b. Total power and peak power normalized against down-slope.

		Surface											
		Down-Slope				Horizontal				Up-Slope			
		TP norm against down-slope		PP norm against down-slope		TP norm against down-slope		PP norm against down-slope		TP norm against down-slope		PP norm against down-slope	
		Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
Channel	GL	100.00	.00	100.00	.00	828.70	1497.37	1253.83	2300.83	104.42	92.10	91.58	54.75
	GM	100.00	.00	100.00	.00	291.41	405.66	275.55	347.54	194.21	236.08	227.13	314.06
	HAM	100.00	.00	100.00	.00	417.30	958.29	625.19	1534.60	99.04	82.15	95.48	75.09
	L3	100.00	.00	100.00	.00	2096.67	6060.69	2762.71	8041.99	6249.25	18508.41	9350.84	27807.75
	T12	100.00	.00	100.00	.00	1362.29	3634.47	1392.66	3640.39	73.97	42.09	74.31	43.96
	TA	100.00	.00	100.00	.00	300.04	395.41	448.67	789.85	228.29	281.81	187.99	211.92
	VL	100.00	.00	100.00	.00	6762.28	19750.86	12302.93	36360.93	90.19	74.40	88.38	71.76
	VM	100.00	.00	100.00	.00	66.48	42.45	68.44	43.79	73.55	42.84	74.94	44.98

Table 12. ANOVA summary table for Median Frequency.

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	9855.733[a]	23	428.510	.882	.620
	Intercept	201675.833	1	201675.833	415.271	.000
	surface	4028.643	2	2014.322	4.148	.020
	chanx	2289.399	7	327.057	.673	.694
	surface * chanx	3537.691	14	252.692	.520	.914
	Error	34966.733	72	485.649		
	Total	246498.299	96			
	Corrected Total	44822.466	95			
Female	Corrected Model	1263.688[b]	23	54.943	1.228	.241
	Intercept	203881.814	1	203881.814	4555.313	.000
	surface	219.108	2	109.554	2.448	.092
	chanx	757.550	7	108.221	2.418	.025
	surface * chanx	287.031	14	20.502	.458	.949
	Error	4296.665	96	44.757		
	Total	209442.168	120			
	Corrected Total	5560.353	119			

a. R Squared = .220 (Adjusted R Squared = -.029)

b. R Squared = .227 (Adjusted R Squared = .042)

Table 13. Post Hoc tests for Median Frequency.

Multiple Comparisons

Dependent Variable: Median Freq (Hz)
Scheffe

gender	(I) Surface			(J) Surface Down-Slope	Horizontal	Up-Slope
Male	Down-Slope	Mean Difference (I-J)			1.2165	-13.0933
		Std. Error			5.50936	5.50936
		Sig.			.976	.066
		95% Confidence Interval	Lower Bound		-12.5545	-26.8643
			Upper Bound		14.9875	.6777
	Horizontal	Mean Difference (I-J)		-1.2165		-14.3098*
		Std. Error		5.50936		5.50936
		Sig.		.976		.040
		95% Confidence Interval	Lower Bound	-14.9875		-28.0808
			Upper Bound	12.5545		-.5388
	Up-Slope	Mean Difference (I-J)		13.0933	14.3098*	
		Std. Error		5.50936	5.50936	
		Sig.		.066	.040	
		95% Confidence Interval	Lower Bound	-.6777	.5388	
			Upper Bound	26.8643	28.0808	
Female	Down-Slope	Mean Difference (I-J)			2.1692	-1.0805
		Std. Error			1.49594	1.49594
		Sig.			.353	.771
		95% Confidence Interval	Lower Bound		-1.5504	-4.8001
			Upper Bound		5.8887	2.6391
	Horizontal	Mean Difference (I-J)		-2.1692		-3.2497
		Std. Error		1.49594		1.49594
		Sig.		.353		.100
		95% Confidence Interval	Lower Bound	-5.8887		-6.9692
			Upper Bound	1.5504		.4699
	Up-Slope	Mean Difference (I-J)		1.0805	3.2497	
		Std. Error		1.49594	1.49594	
		Sig.		.771	.100	
		95% Confidence Interval	Lower Bound	-2.6391	-.4699	
			Upper Bound	4.8001	6.9692	

Based on observed means.

*. The mean difference is significant at the .05 level.

Table 14. ANOVA summary table for Mean Power Frequency.

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	10315.120[a]	23	448.483	.965	.518
	Intercept	323167.292	1	323167.292	695.696	.000
	surface	4475.528	2	2237.764	4.817	.011
	chanx	2854.393	7	407.770	.878	.528
	surface * chanx	2985.199	14	213.228	.459	.947
	Error	33445.731	72	464.524		
	Total	366928.143	96			
	Corrected Total	43760.851	95			
Female	Corrected Model	2452.913[b]	23	106.648	1.761	.030
	Intercept	356075.401	1	356075.401	5879.243	.000
	surface	317.076	2	158.538	2.618	.078
	chanx	1827.270	7	261.039	4.310	.000
	surface * chanx	308.567	14	22.041	.364	.982
	Error	5814.224	96	60.565		
	Total	364342.538	120			
	Corrected Total	8267.138	119			

a. R Squared = .236 (Adjusted R Squared = -.008)

b. R Squared = .297 (Adjusted R Squared = .128)

Table 15. Post Hoc tests for Mean Power Frequency.

Multiple Comparisons

Dependent Variable: Mean Power Freq (Hz)
Scheffe

gender	(I) Surface			(J) Surface Down-Slope	Horizontal	Up-Slope
Male	Down-Slope	Mean Difference (I-J)			.7537	-14.0926*
		Std. Error			5.38820	5.38820
		Sig.			.990	.038
		95% Confidence Interval	Lower Bound		-12.7144	-27.5607
			Upper Bound		14.2219	-.6244
	Horizontal	Mean Difference (I-J)		-.7537		-14.8463*
		Std. Error		5.38820		5.38820
		Sig.		.990		.027
		95% Confidence Interval	Lower Bound	-14.2219		-28.3144
			Upper Bound	12.7144		-1.3781
	Up-Slope	Mean Difference (I-J)		14.0926*	14.8463*	
		Std. Error		5.38820	5.38820	
		Sig.		.038	.027	
		95% Confidence Interval	Lower Bound	.6244	1.3781	
			Upper Bound	27.5607	28.3144	
Female	Down-Slope	Mean Difference (I-J)			2.7099	-1.1715
		Std. Error			1.74018	1.74018
		Sig.			.302	.798
		95% Confidence Interval	Lower Bound		-1.6170	-5.4983
			Upper Bound		7.0368	3.1554
	Horizontal	Mean Difference (I-J)		-2.7099		-3.8813
		Std. Error		1.74018		1.74018
		Sig.		.302		.088
		95% Confidence Interval	Lower Bound	-7.0368		-8.2082
			Upper Bound	1.6170		.4455
	Up-Slope	Mean Difference (I-J)		1.1715	3.8813	
		Std. Error		1.74018	1.74018	
		Sig.		.798	.088	
		95% Confidence Interval	Lower Bound	-3.1554	-.4455	
			Upper Bound	5.4983	8.2082	

Based on observed means.

*. The mean difference is significant at the .05 level.

Table 16. ANOVA summary table for Median Frequency normalized against down-slope.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	100920.392[a]	47	2147.242	1.036	.423
Intercept	2391475.818	1	2391475.818	1153.713	.000
gender	8632.802	1	8632.802	4.165	.043
surface	24626.319	2	12313.159	5.940	.003
chanx	9322.977	7	1331.854	.643	.720
gender * surface	14704.481	2	7352.241	3.547	.031
gender * chanx	12054.449	7	1722.064	.831	.563
surface * chanx	20563.519	14	1468.823	.709	.764
gender * surface * chanx	20506.181	14	1464.727	.707	.766
Error	348239.150	168	2072.852		
Total	2838307.783	216			
Corrected Total	449159.542	215			

a. R Squared = .225 (Adjusted R Squared = .008)

Table 17. ANOVA summary table for Mean Power Frequency normalized against down-slope.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	73506.067[a]	47	1563.959	1.007	.471
Intercept	2378861.980	1	2378861.980	1531.605	.000
gender	7858.705	1	7858.705	5.060	.026
surface	20239.987	2	10119.993	6.516	.002
chanx	7393.822	7	1056.260	.680	.689
gender * surface	11850.766	2	5925.383	3.815	.024
gender * chanx	6494.542	7	927.792	.597	.757
surface * chanx	13613.394	14	972.385	.626	.841
gender * surface * chanx	12756.835	14	911.203	.587	.873
Error	260934.644	168	1553.182		
Total	2712372.711	216			
Corrected Total	334440.711	215			

a. R Squared = .220 (Adjusted R Squared = .002)

Table 18. Post Hoc multiple comparison of the Median Frequency normalized against down-slope.

(I) Surface			(J) Surface		
			Down-Slope	Horizontal	Up-Slope
Down-Slope	Mean Difference (I-J)			3.4288	-18.9409*
	Std. Error			7.58810	7.58810
	Sig.			.903	.047
	95% Confidence Interval	Lower Bound		-15.3117	-37.6815
		Upper Bound		22.1694	-.2003
Horizontal	Mean Difference (I-J)		-3.4288		-22.3697*
	Std. Error		7.58810		7.58810
	Sig.		.903		.014
	95% Confidence Interval	Lower Bound	-22.1694		-41.1103
		Upper Bound	15.3117		-3.6291
Up-Slope	Mean Difference (I-J)		18.9409*	22.3697*	
	Std. Error		7.58810	7.58810	
	Sig.		.047	.014	
	95% Confidence Interval	Lower Bound	.2003	3.6291	
		Upper Bound	37.6815	41.1103	

Based on observed means.

*. The mean difference is significant at the .05 level.

Table 41. Post Hoc tests for right and left external obliques.

A. Right External Oblique

gender	(I) surface	(J) surface	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Male	Down-Slope	Horizontal	-15.9387*	4.27384	.002	-26.6970	-5.1804
		Up-Slope	-9.8227	4.27384	.080	-20.5810	.9356
	Horizontal	Down-Slope	15.9387*	4.27384	.002	5.1804	26.6970
		Up-Slope	6.1160	4.27384	.366	-4.6423	16.8743
	Up-Slope	Down-Slope	9.8227	4.27384	.080	-.9356	20.5810
		Horizontal	-6.1160	4.27384	.366	-16.8743	4.6423
Female	Down-Slope	Horizontal	-5.0411	3.72343	.405	-14.3480	4.2659
		Up-Slope	-17.0507*	3.72343	.000	-26.3576	-7.7437
	Horizontal	Down-Slope	5.0411	3.72343	.405	-4.2659	14.3480
		Up-Slope	-12.0096*	3.72343	.008	-21.3166	-2.7026
	Up-Slope	Down-Slope	17.0507*	3.72343	.000	7.7437	26.3576
		Horizontal	12.0096*	3.72343	.008	2.7026	21.3166

Based on observed means.

*. The mean difference is significant at the .05 level.

B. Left External Oblique

gender	(I) surface	(J) surface	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Male	Down-Slope	Horizontal	-16.1240*	4.27652	.002	-26.8890	-5.3590
		Up-Slope	-9.8227	4.27652	.081	-20.5877	.9424
	Horizontal	Down-Slope	16.1240*	4.27652	.002	5.3590	26.8890
		Up-Slope	6.3013	4.27652	.345	-4.4637	17.0664
	Up-Slope	Down-Slope	9.8227	4.27652	.081	-.9424	20.5877
		Horizontal	-6.3013	4.27652	.345	-17.0664	4.4637
Female	Down-Slope	Horizontal	-4.8928	3.80037	.441	-14.3921	4.6065
		Up-Slope	-17.4955*	3.80037	.000	-26.9947	-7.9962
	Horizontal	Down-Slope	4.8928	3.80037	.441	-4.6065	14.3921
		Up-Slope	-12.6027*	3.80037	.006	-22.1019	-3.1034
	Up-Slope	Down-Slope	17.4955*	3.80037	.000	7.9962	26.9947
		Horizontal	12.6027*	3.80037	.006	3.1034	22.1019

Based on observed means.

*. The mean difference is significant at the .05 level.

Table 19. Post Hoc multiple comparison of Mean Power Frequency normalized against down-slope.

Multiple Comparisons

(I) Surface			(J) Surface Down-Slope	Horizontal	Up-Slope
Down-Slope	Mean Difference (I-J)			2.6855	-17.4560*
	Std. Error			6.56841	6.56841
	Sig.			.920	.031
	95% Confidence Interval	Lower Bound		-13.5367	-33.6783
		Upper Bound		18.9077	-1.2338
Horizontal	Mean Difference (I-J)		-2.6855		-20.1415*
	Std. Error		6.56841		6.56841
	Sig.		.920		.010
	95% Confidence Interval	Lower Bound	-18.9077		-36.3638
		Upper Bound	13.5367		-3.9193
Up-Slope	Mean Difference (I-J)		17.4560*	20.1415*	
	Std. Error		6.56841	6.56841	
	Sig.		.031	.010	
	95% Confidence Interval	Lower Bound	1.2338	3.9193	
		Upper Bound	33.6783	36.3638	

Based on observed means.

*. The mean difference is significant at the .05 level.

Table 20. ANOVA summary table for Total Power normalized against down-slope.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1484904680[a]	47	31593716.597	.968	.538
Intercept	147377423.4	1	147377423.40	4.514	.035
gender	244030.328	1	244030.328	.007	.931
surface	63414748.530	2	31707374.265	.971	.381
chanx	224651597.6	7	32093085.377	.983	.445
gender * surface	118304685.6	2	59152342.824	1.812	.167
gender * chanx	194087962.4	7	27726851.772	.849	.548
surface * chanx	394213762.1	14	28158125.865	.862	.601
gender * surface * chanx	492290425.6	14	35163601.826	1.077	.382
Error	5485005644	168	32648843.122		
Total	7120482351	216			
Corrected Total	6969910324	215			

a. R Squared = .213 (Adjusted R Squared = -.007)

Table 21. ANOVA summary table for Peak Power normalized against down-slope.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4048259557[a]	47	86133182.065	.944	.579
Intercept	326991861.5	1	326991861.53	3.585	.060
gender	4978240.898	1	4978240.898	.055	.816
surface	159761272.2	2	79880636.090	.876	.418
chanx	576135619.8	7	82305088.537	.902	.506
gender * surface	331136755.7	2	165568377.86	1.815	.166
gender * chanx	557130386.7	7	79590055.244	.873	.529
surface * chanx	1104282098	14	78877292.716	.865	.598
gender * surface * chanx	1237847827	14	88417701.921	.969	.487
Error	15323871600	168	91213521.430		
Total	19712350619	216			
Corrected Total	19372131157	215			

a. R Squared = .209 (Adjusted R Squared = -.012)

Table 22. Median Frequency and Mean Power Frequency normalized against down-slope for male and female samples.

			Surface											
			Down-Slope				Horizontal				Up-Slope			
			MF norm against down-slope		MPF norm against down-slope		MF norm against down-slope		MPF norm against down-slope		MF norm against down-slope		MPF norm against down-slope	
gender			Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
Male	Channel	GL	100.00	.00	100.00	.00	99.96	7.89	98.93	8.98	131.82	47.95	131.95	47.72
		GM	100.00	.00	100.00	.00	106.23	25.92	104.53	19.09	103.29	13.62	103.05	9.31
		HAM	100.00	.00	100.00	.00	102.33	21.64	105.35	13.09	117.88	27.69	118.07	31.16
		L3	100.00	.00	100.00	.00	100.97	10.93	104.06	15.75	235.13	283.79	210.78	235.23
		T12	100.00	.00	100.00	.00	94.70	3.02	91.12	6.42	168.51	138.92	156.86	120.16
		TA	100.00	.00	100.00	.00	99.09	8.74	101.76	14.77	113.91	20.52	122.48	36.30
		VL	100.00	.00	100.00	.00	86.09	9.16	90.23	12.13	113.35	51.82	107.09	40.30
		VM	100.00	.00	100.00	.00	92.05	8.22	97.13	5.70	128.42	69.62	136.63	81.03
Female	Channel	GL	100.00	.00	100.00	.00	90.62	8.54	89.41	12.46	96.61	4.21	98.32	5.12
		GM	100.00	.00	100.00	.00	98.25	16.69	95.66	8.91	93.91	6.61	94.64	7.03
		HAM	100.00	.00	100.00	.00	94.56	10.61	93.24	11.94	100.82	10.44	99.41	6.26
		L3	100.00	.00	100.00	.00	92.55	16.04	97.15	13.37	101.72	12.68	105.80	18.24
		T12	100.00	.00	100.00	.00	95.37	1.59	96.47	3.53	101.51	7.22	101.66	7.46
		TA	100.00	.00	100.00	.00	99.19	11.66	94.21	7.84	117.80	22.60	111.43	16.25
		VL	100.00	.00	100.00	.00	95.92	24.19	97.16	23.60	110.30	12.19	109.29	10.23
		VM	100.00	.00	100.00	.00	99.03	7.98	103.55	11.02	100.24	7.58	101.29	10.78

Table 23. ANOVA summary table for Median Frequency normalized against down-slope.

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	88850.309[a]	23	3863.057	.823	.692
	Intercept	1209364.617	1	1209364.617	257.766	.000
	surface	34562.543	2	17281.272	3.683	.030
	chanx	18440.695	7	2634.385	.561	.785
	surface * chanx	35847.071	14	2560.505	.546	.897
	Error	337803.172	72	4691.711		
	Total	1636018.098	96			
	Corrected Total	426653.481	95			
Female	Corrected Model	3437.282[b]	23	149.447	1.375	.144
	Intercept	1188416.425	1	1188416.425	10932.178	.000
	surface	1043.971	2	521.986	4.802	.010
	chanx	998.736	7	142.677	1.312	.253
	surface * chanx	1394.575	14	99.612	.916	.544
	Error	10435.978	96	108.708		
	Total	1202289.685	120			
	Corrected Total	13873.260	119			

a. R Squared = .208 (Adjusted R Squared = -.045)

b. R Squared = .248 (Adjusted R Squared = .068)

Table 24. ANOVA summary table for Mean Power Frequency normalized against down-slope.

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	62982.613[a]	23	2738.374	.783	.740
	Intercept	1197080.261	1	1197080.261	342.364	.000
	surface	28115.006	2	14057.503	4.020	.022
	chanx	11977.454	7	1711.065	.489	.839
	surface * chanx	22890.152	14	1635.011	.468	.943
	Error	251748.646	72	3496.509		
	Total	1511811.520	96			
	Corrected Total	314731.259	95			
Female	Corrected Model	2664.749[b]	23	115.859	1.211	.255
	Intercept	1188710.445	1	1188710.445	12422.842	.000
	surface	958.339	2	479.170	5.008	.009
	chanx	652.591	7	93.227	.974	.455
	surface * chanx	1053.818	14	75.273	.787	.681
	Error	9185.998	96	95.687		
	Total	1200561.191	120			
	Corrected Total	11850.747	119			

a. R Squared = .200 (Adjusted R Squared = -.055)

b. R Squared = .225 (Adjusted R Squared = .039)

Table 25. Spinal compression and shear while standing on three surfaces among male and female samples.

		L5/S1 Disc Compression		L5/S1 Sagittal Shear		L4/L5 Disc Compression		L4/L5 Disc AP Shear	
		Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
Male	Down-Slope	422.37	53.43	218.88	11.21	358.06	45.81	139.19	7.00
	Horizontal	373.82	94.61	210.72	12.01	405.51	85.01	126.21	13.43
	Up-Slope	431.64	143.88	216.47	14.29	430.53	93.00	135.11	14.24
Female	Down-Slope	362.22	106.81	182.07	26.43	343.83	97.42	115.20	16.37
	Horizontal	290.31	73.71	180.59	28.05	316.99	60.50	114.61	16.75
	Up-Slope	296.24	77.18	175.84	24.74	359.84	127.62	109.42	15.83

Table 26. Forces generated by dorsal muscles.

gender		RES resultant force		LES resultant force		RLD resultant force		LLD resultant force	
		Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
Male	Down-Slope	27.61	15.46	28.36	15.46	5.56	2.74	5.56	2.74
	Horizontal	16.49	31.52	16.68	31.89	3.52	7.04	3.52	7.04
	Up-Slope	40.40	51.47	41.89	53.05	9.08	11.90	9.08	11.90
Female	Down-Slope	35.29	35.27	34.99	34.92	2.67	2.65	2.82	2.94
	Horizontal	9.64	10.69	9.64	10.69	.74	.74	.74	.74
	Up-Slope	2.08	3.53	2.08	3.53	.15	.33	.15	.33

Table 27. Forces generated by ventral muscles.

		RRA resultant force		LRA resultant force		RIO resultant force		LIO resultant force		REO resultant force		LEO resultant force	
gender		Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
Male	Down-Slope	.37	.74	.37	.74	.37	.74	.37	.74	.37	.74	.37	.74
	Horizontal	13.34	15.13	12.97	14.89	14.64	17.22	14.83	17.57	16.31	19.56	16.49	19.52
	Up-Slope	8.34	11.54	7.23	10.49	8.71	12.23	8.90	12.24	10.19	14.33	10.19	14.33
Female	Down-Slope	4.15	8.87	4.30	9.21	5.49	11.86	5.19	11.19	4.60	9.87	4.74	10.20
	Horizontal	8.75	5.53	8.90	5.74	11.12	7.54	10.82	7.12	9.64	6.57	9.64	6.57
	Up-Slope	18.39	17.27	18.83	17.87	25.06	22.54	24.91	22.57	21.65	19.39	22.24	19.84

Table 28. ANOVA summary table for lumbosacral compression.

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	4313.236[a]	17	253.720	.383	.984
	Intercept	609592.014	1	609592.014	919.041	.000
	surface	2340.111	2	1170.056	1.764	.181
	frameno	855.403	5	171.081	.258	.934
	surface * frameno	1117.722	10	111.772	.169	.998
	Error	35817.750	54	663.292		
	Total	649723.000	72			
	Corrected Total	40130.986	71			
Female	Corrected Model	6768.900[b]	17	398.171	.911	.565
	Intercept	454968.900	1	454968.900	1040.550	.000
	surface	4831.667	2	2415.833	5.525	.006
	frameno	535.967	5	107.193	.245	.941
	surface * frameno	1401.267	10	140.127	.320	.973
	Error	31481.200	72	437.239		
	Total	493219.000	90			
	Corrected Total	38250.100	89			

a. R Squared = .107 (Adjusted R Squared = -.173)

b. R Squared = .177 (Adjusted R Squared = -.017)

Table 29. ANOVA summary table for L4/L5 compression.

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	4033.736[a]	17	237.279	.636	.848
	Intercept	576559.014	1	576559.014	1545.255	.000
	surface	3286.694	2	1643.347	4.404	.017
	frameno	378.903	5	75.781	.203	.960
	surface * frameno	368.139	10	36.814	.099	1.000
	Error	20148.250	54	373.116		
	Total	600741.000	72			
	Corrected Total	24181.986	71			
Female	Corrected Model	3560.889[b]	17	209.464	.368	.988
	Intercept	526549.511	1	526549.511	924.456	.000
	surface	1421.622	2	710.811	1.248	.293
	frameno	167.289	5	33.458	.059	.998
	surface * frameno	1971.978	10	197.198	.346	.965
	Error	41009.600	72	569.578		
	Total	571120.000	90			
	Corrected Total	44570.489	89			

a. R Squared = .167 (Adjusted R Squared = -.095)

b. R Squared = .080 (Adjusted R Squared = -.137)

Table 30. Post Hoc test for lumbosacral compression.

Multiple Comparisons

Dependent Variable: L5/S1 disc compression
Scheffe

gender	(I) surface			(J) surface Down-Slope	Horizontal	Up-Slope
Male	Down-Slope	Mean Difference (I-J)			10.9167	-2.0833
		Std. Error			7.43467	7.43467
		Sig.			.347	.962
		95% Confidence Interval	Lower Bound		-7.7982	-20.7982
			Upper Bound		29.6315	16.6315
	Horizontal	Mean Difference (I-J)		-10.9167		-13.0000
		Std. Error		7.43467		7.43467
		Sig.		.347		.226
		95% Confidence Interval	Lower Bound	-29.6315		-31.7148
			Upper Bound	7.7982		5.7148
	Up-Slope	Mean Difference (I-J)		2.0833	13.0000	
		Std. Error		7.43467	7.43467	
		Sig.		.962	.226	
		95% Confidence Interval	Lower Bound	-16.6315	-5.7148	
			Upper Bound	20.7982	31.7148	
Female	Down-Slope	Mean Difference (I-J)			16.1667*	14.8333*
		Std. Error			5.39901	5.39901
		Sig.			.015	.028
		95% Confidence Interval	Lower Bound		2.6715	1.3382
			Upper Bound		29.6618	28.3285
	Horizontal	Mean Difference (I-J)		-16.1667*		-1.3333
		Std. Error		5.39901		5.39901
		Sig.		.015		.970
		95% Confidence Interval	Lower Bound	-29.6618		-14.8285
			Upper Bound	-2.6715		12.1618
	Up-Slope	Mean Difference (I-J)		-14.8333*	1.3333	
		Std. Error		5.39901	5.39901	
		Sig.		.028	.970	
		95% Confidence Interval	Lower Bound	-28.3285	-12.1618	
			Upper Bound	-1.3382	14.8285	

Based on observed means.

*. The mean difference is significant at the .05 level.

Table 31. Post Hoc test for L4/L5 compression.

Multiple Comparisons

Dependent Variable: L4/L5 Disc Compression
Scheffe

gender	(I) surface			(J) surface Down-Slope	Horizontal	Up-Slope
Male	Down-Slope	Mean Difference (I-J)			-47.4509	-72.4738*
		Std. Error			24.80543	24.80543
		Sig.			.170	.019
		95% Confidence Interval	Lower Bound		-109.8921	-134.9150
			Upper Bound		14.9903	-10.0326
	Horizontal	Mean Difference (I-J)		47.4509		-25.0229
		Std. Error		24.80543		24.80543
		Sig.		.170		.604
		95% Confidence Interval	Lower Bound	-14.9903		-87.4641
			Upper Bound	109.8921		37.4183
	Up-Slope	Mean Difference (I-J)		72.4738*	25.0229	
		Std. Error		24.80543	24.80543	
		Sig.		.019	.604	
		95% Confidence Interval	Lower Bound	10.0326	-37.4183	
			Upper Bound	134.9150	87.4641	
Female	Down-Slope	Mean Difference (I-J)			26.8394	-16.0147
		Std. Error			27.41236	27.41236
		Sig.			.621	.843
		95% Confidence Interval	Lower Bound		-41.6795	-84.5336
			Upper Bound		95.3583	52.5042
	Horizontal	Mean Difference (I-J)		-26.8394		-42.8541
		Std. Error		27.41236		27.41236
		Sig.		.621		.301
		95% Confidence Interval	Lower Bound	-95.3583		-111.3730
			Upper Bound	41.6795		25.6648
	Up-Slope	Mean Difference (I-J)		16.0147	42.8541	
		Std. Error		27.41236	27.41236	
		Sig.		.843	.301	
		95% Confidence Interval	Lower Bound	-52.5042	-25.6648	
			Upper Bound	84.5336	111.3730	

Based on observed means.

*. The mean difference is significant at the .05 level.

Table 32. ANOVA summary table for right and left erectores spinae.

A. Right Erectores Spinae

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	11020.080[a]	17	648.240	.441	.967
	Intercept	57138.225	1	57138.225	38.881	.000
	surface	6870.238	2	3435.119	2.338	.106
	frameno	2054.312	5	410.862	.280	.922
	surface * frameno	2095.530	10	209.553	.143	.999
	Error	79356.448	54	1469.564		
	Total	147514.753	72			
	Corrected Total	90376.528	71			
Female	Corrected Model	24462.907[b]	17	1438.995	2.063	.018
	Intercept	22090.501	1	22090.501	31.675	.000
	surface	18181.264	2	9090.632	13.035	.000
	frameno	2356.798	5	471.360	.676	.643
	surface * frameno	3924.846	10	392.485	.563	.839
	Error	50213.579	72	697.411		
	Total	96766.987	90			
	Corrected Total	74676.486	89			

a. R Squared = .122 (Adjusted R Squared = -.154)

b. R Squared = .328 (Adjusted R Squared = .169)

B. Left Erectores Spinae

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	11885.386[a]	17	699.140	.454	.963
	Intercept	60442.546	1	60442.546	39.211	.000
	surface	7637.445	2	3818.723	2.477	.093
	frameno	1983.142	5	396.628	.257	.934
	surface * frameno	2264.799	10	226.480	.147	.999
	Error	83239.196	54	1541.467		
	Total	155567.128	72			
	Corrected Total	95124.582	71			
Female	Corrected Model	24178.887[b]	17	1422.287	2.054	.019
	Intercept	21812.636	1	21812.636	31.495	.000
	surface	17833.932	2	8916.966	12.875	.000
	frameno	2399.885	5	479.977	.693	.630
	surface * frameno	3945.070	10	394.507	.570	.833
	Error	49865.368	72	692.575		
	Total	95856.891	90			
	Corrected Total	74044.255	89			

a. R Squared = .125 (Adjusted R Squared = -.151)

b. R Squared = .327 (Adjusted R Squared = .168)

Table 33. Post Hoc tests for right and left erector spinae.

A. Right Erectores Spinae

gender	(I) surface	(J) surface	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Male	Down-Slope	Horizontal	11.1200	11.06633	.606	-16.7366	38.9766
		Up-Slope	-12.7880	11.06633	.517	-40.6446	15.0686
	Horizontal	Down-Slope	-11.1200	11.06633	.606	-38.9766	16.7366
		Up-Slope	-23.9080	11.06633	.107	-51.7646	3.9486
	Up-Slope	Down-Slope	12.7880	11.06633	.517	-15.0686	40.6446
		Horizontal	23.9080	11.06633	.107	-3.9486	51.7646
Female	Down-Slope	Horizontal	25.6501*	6.81865	.002	8.6065	42.6938
		Up-Slope	33.2117*	6.81865	.000	16.1681	50.2554
	Horizontal	Down-Slope	-25.6501*	6.81865	.002	-42.6938	-8.6065
		Up-Slope	7.5616	6.81865	.544	-9.4821	24.6053
	Up-Slope	Down-Slope	-33.2117*	6.81865	.000	-50.2554	-16.1681
		Horizontal	-7.5616	6.81865	.544	-24.6053	9.4821

Based on observed means.

*. The mean difference is significant at the .05 level.

B. Left Erectores Spinae

gender	(I) surface	(J) surface	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Male	Down-Slope	Horizontal	11.6760	11.33382	.591	-16.8539	40.2059
		Up-Slope	-13.5293	11.33382	.495	-42.0593	15.0006
	Horizontal	Down-Slope	-11.6760	11.33382	.591	-40.2059	16.8539
		Up-Slope	-25.2053	11.33382	.094	-53.7353	3.3246
	Up-Slope	Down-Slope	13.5293	11.33382	.495	-15.0006	42.0593
		Horizontal	25.2053	11.33382	.094	-3.3246	53.7353
Female	Down-Slope	Horizontal	25.3536*	6.79497	.002	8.3691	42.3381
		Up-Slope	32.9152*	6.79497	.000	15.9307	49.8997
	Horizontal	Down-Slope	-25.3536*	6.79497	.002	-42.3381	-8.3691
		Up-Slope	7.5616	6.79497	.541	-9.4229	24.5461
	Up-Slope	Down-Slope	-32.9152*	6.79497	.000	-49.8997	-15.9307
		Horizontal	-7.5616	6.79497	.541	-24.5461	9.4229

Based on observed means.

*. The mean difference is significant at the .05 level.

Table 34. ANOVA summary table for right and left latissimus dorsi

A. Right Latissimus Dorsi

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	536.385[a]	17	31.552	.427	.972
	Intercept	2639.060	1	2639.060	35.747	.000
	surface	379.756	2	189.878	2.572	.086
	frameno	71.445	5	14.289	.194	.964
	surface * frameno	85.184	10	8.518	.115	1.000
	Error	3986.618	54	73.826		
	Total	7162.063	72			
	Corrected Total	4523.003	71			
Female	Corrected Model	158.278[b]	17	9.310	1.925	.029
	Intercept	126.622	1	126.622	26.182	.000
	surface	104.199	2	52.100	10.773	.000
	frameno	23.742	5	4.748	.982	.435
	surface * frameno	30.337	10	3.034	.627	.786
	Error	348.211	72	4.836		
	Total	633.111	90			
	Corrected Total	506.488	89			

a. R Squared = .119 (Adjusted R Squared = -.159)

b. R Squared = .313 (Adjusted R Squared = .150)

B. Left Latissimus Dorsi

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	536.385[a]	17	31.552	.427	.972
	Intercept	2639.060	1	2639.060	35.747	.000
	surface	379.756	2	189.878	2.572	.086
	frameno	71.445	5	14.289	.194	.964
	surface * frameno	85.184	10	8.518	.115	1.000
	Error	3986.618	54	73.826		
	Total	7162.063	72			
	Corrected Total	4523.003	71			
Female	Corrected Model	175.205[b]	17	10.306	1.953	.026
	Intercept	137.394	1	137.394	26.042	.000
	surface	117.829	2	58.914	11.167	.000
	frameno	27.479	5	5.496	1.042	.400
	surface * frameno	29.897	10	2.990	.567	.836
	Error	379.866	72	5.276		
	Total	692.465	90			
	Corrected Total	555.071	89			

a. R Squared = .119 (Adjusted R Squared = -.159)

b. R Squared = .316 (Adjusted R Squared = .154)

Table 35. Post Hoc tests for right and left latissimus dorsi.

A. Right Latissimus Dorsi

gender	(I) surface	(J) surface	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Male	Down-Slope	Horizontal	2.0387	2.48036	.715	-4.2050	8.2823
		Up-Slope	-3.5213	2.48036	.372	-9.7650	2.7223
	Horizontal	Down-Slope	-2.0387	2.48036	.715	-8.2823	4.2050
		Up-Slope	-5.5600	2.48036	.091	-11.8037	.6837
	Up-Slope	Down-Slope	3.5213	2.48036	.372	-2.7223	9.7650
		Horizontal	5.5600	2.48036	.091	-.6837	11.8037
Female	Down-Slope	Horizontal	1.9275*	.56782	.005	.5082	3.3468
		Up-Slope	2.5205*	.56782	.000	1.1012	3.9398
	Horizontal	Down-Slope	-1.9275*	.56782	.005	-3.3468	-.5082
		Up-Slope	.5931	.56782	.582	-.8262	2.0124
	Up-Slope	Down-Slope	-2.5205*	.56782	.000	-3.9398	-1.1012
		Horizontal	-.5931	.56782	.582	-2.0124	.8262

Based on observed means.

*. The mean difference is significant at the .05 level.

B. Left Latissimus Dorsi

gender	(I) surface	(J) surface	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Male	Down-Slope	Horizontal	2.0387	2.48036	.715	-4.2050	8.2823
		Up-Slope	-3.5213	2.48036	.372	-9.7650	2.7223
	Horizontal	Down-Slope	-2.0387	2.48036	.715	-8.2823	4.2050
		Up-Slope	-5.5600	2.48036	.091	-11.8037	.6837
	Up-Slope	Down-Slope	3.5213	2.48036	.372	-2.7223	9.7650
		Horizontal	5.5600	2.48036	.091	-.6837	11.8037
Female	Down-Slope	Horizontal	2.0757*	.59307	.003	.5933	3.5581
		Up-Slope	2.6688*	.59307	.000	1.1864	4.1512
	Horizontal	Down-Slope	-2.0757*	.59307	.003	-3.5581	-.5933
		Up-Slope	.5931	.59307	.609	-.8893	2.0755
	Up-Slope	Down-Slope	-2.6688*	.59307	.000	-4.1512	-1.1864
		Horizontal	-.5931	.59307	.609	-2.0755	.8893

Based on observed means.

*. The mean difference is significant at the .05 level.

Table 36. ANOVA summary table for right and left rectus abdominis.

A. Right Rectus Abdominis

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	2385.431[a]	17	140.319	1.025	.448
	Intercept	3891.267	1	3891.267	28.417	.000
	surface	2054.861	2	1027.431	7.503	.001
	frameno	199.221	5	39.844	.291	.916
	surface * frameno	131.348	10	13.135	.096	1.000
	Error	7394.533	54	136.936		
	Total	13671.230	72			
	Corrected Total	9779.964	71			
Female	Corrected Model	4295.699[b]	17	252.688	1.530	.109
	Intercept	9787.053	1	9787.053	59.243	.000
	surface	3165.992	2	1582.996	9.582	.000
	frameno	613.106	5	122.621	.742	.594
	surface * frameno	516.601	10	51.660	.313	.976
	Error	11894.564	72	165.202		
	Total	25977.316	90			
	Corrected Total	16190.263	89			

a. R Squared = .244 (Adjusted R Squared = .006)

b. R Squared = .265 (Adjusted R Squared = .092)

B. Left Rectus Abdominis

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	2218.360[a]	17	130.492	1.055	.420
	Intercept	3385.657	1	3385.657	27.360	.000
	surface	1910.873	2	955.436	7.721	.001
	frameno	170.643	5	34.129	.276	.924
	surface * frameno	136.844	10	13.684	.111	1.000
	Error	6682.284	54	123.746		
	Total	12286.301	72			
	Corrected Total	8900.644	71			
Female	Corrected Model	4605.879[b]	17	270.934	1.506	.117
	Intercept	10256.391	1	10256.391	57.002	.000
	surface	3309.321	2	1654.661	9.196	.000
	frameno	691.146	5	138.229	.768	.576
	surface * frameno	605.412	10	60.541	.336	.968
	Error	12955.024	72	179.931		
	Total	27817.294	90			
	Corrected Total	17560.903	89			

a. R Squared = .249 (Adjusted R Squared = .013)

b. R Squared = .262 (Adjusted R Squared = .088)

Table 37. ANOVA summary table for right and left internal obliques.

A. Right Internal Oblique

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	2828.114[a]	17	166.360	1.001	.471
	Intercept	4502.119	1	4502.119	27.096	.000
	surface	2467.043	2	1233.521	7.424	.001
	frameno	203.343	5	40.669	.245	.941
	surface * frameno	157.728	10	15.773	.095	1.000
	Error	8972.363	54	166.155		
	Total	16302.596	72			
	Corrected Total	11800.477	71			
Female	Corrected Model	8025.775[b]	17	472.104	1.649	.074
	Intercept	17358.000	1	17358.000	60.623	.000
	surface	6090.172	2	3045.086	10.635	.000
	frameno	1074.749	5	214.950	.751	.588
	surface * frameno	860.854	10	86.085	.301	.979
	Error	20615.662	72	286.329		
	Total	45999.437	90			
	Corrected Total	28641.437	89			

a. R Squared = .240 (Adjusted R Squared = .000)

b. R Squared = .280 (Adjusted R Squared = .110)

B. Left Internal Oblique

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	2963.309[a]	17	174.312	1.018	.455
	Intercept	4643.910	1	4643.910	27.112	.000
	surface	2534.640	2	1267.320	7.399	.001
	frameno	233.020	5	46.604	.272	.926
	surface * frameno	195.649	10	19.565	.114	1.000
	Error	9249.349	54	171.284		
	Total	16856.568	72			
	Corrected Total	12212.658	71			
Female	Corrected Model	8143.384[b]	17	479.023	1.716	.059
	Intercept	16745.773	1	16745.773	59.981	.000
	surface	6189.974	2	3094.987	11.086	.000
	frameno	1034.081	5	206.816	.741	.595
	surface * frameno	919.329	10	91.933	.329	.971
	Error	20101.259	72	279.184		
	Total	44990.417	90			
	Corrected Total	28244.643	89			

a. R Squared = .243 (Adjusted R Squared = .004)

b. R Squared = .288 (Adjusted R Squared = .120)

Table 38. ANOVA summary table for right and left external obliques.

A. Right External Oblique

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	3575.810[a]	17	210.342	.960	.514
	Intercept	5777.408	1	5777.408	26.358	.000
	surface	3103.451	2	1551.725	7.079	.002
	frameno	261.873	5	52.375	.239	.944
	surface * frameno	210.487	10	21.049	.096	1.000
	Error	11836.199	54	219.189		
	Total	21189.418	72			
	Corrected Total	15412.010	71			
Female	Corrected Model	6261.639[b]	17	368.332	1.771	.049
	Intercept	12874.127	1	12874.127	61.907	.000
	surface	4603.681	2	2301.840	11.069	.000
	frameno	972.528	5	194.506	.935	.463
	surface * frameno	685.430	10	68.543	.330	.970
	Error	14973.064	72	207.959		
	Total	34108.830	90			
	Corrected Total	21234.703	89			

a. R Squared = .232 (Adjusted R Squared = -.010)

b. R Squared = .295 (Adjusted R Squared = .128)

B. Left External Oblique

gender	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Male	Corrected Model	3698.640[a]	17	217.567	.991	.481
	Intercept	5857.372	1	5857.372	26.689	.000
	surface	3169.400	2	1584.700	7.221	.002
	frameno	285.779	5	57.156	.260	.933
	surface * frameno	243.462	10	24.346	.111	1.000
	Error	11851.038	54	219.464		
	Total	21407.050	72			
	Corrected Total	15549.678	71			
Female	Corrected Model	6464.102[b]	17	380.241	1.755	.052
	Intercept	13411.611	1	13411.611	61.907	.000
	surface	4888.581	2	2444.290	11.283	.000
	frameno	924.385	5	184.877	.853	.517
	surface * frameno	651.137	10	65.114	.301	.979
	Error	15598.261	72	216.643		
	Total	35473.974	90			
	Corrected Total	22062.363	89			

a. R Squared = .238 (Adjusted R Squared = -.002)

b. R Squared = .293 (Adjusted R Squared = .126)

Table 39. Post Hoc tests for right and left rectus abdominis.

A. Right Rectus Abdominis

gender	(I) surface	(J) surface	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Male	Down-Slope	Horizontal	-12.9733*	3.37806	.001	-21.4767	-4.4699
		Up-Slope	-7.9693	3.37806	.071	-16.4727	.5341
	Horizontal	Down-Slope	12.9733*	3.37806	.001	4.4699	21.4767
		Up-Slope	5.0040	3.37806	.341	-3.4994	13.5074
	Up-Slope	Down-Slope	7.9693	3.37806	.071	-.5341	16.4727
		Horizontal	-5.0040	3.37806	.341	-13.5074	3.4994
Female	Down-Slope	Horizontal	-4.5963	3.31866	.388	-12.8915	3.6989
		Up-Slope	-14.2336*	3.31866	.000	-22.5288	-5.9384
	Horizontal	Down-Slope	4.5963	3.31866	.388	-3.6989	12.8915
		Up-Slope	-9.6373*	3.31866	.019	-17.9325	-1.3421
	Up-Slope	Down-Slope	14.2336*	3.31866	.000	5.9384	22.5288
		Horizontal	9.6373*	3.31866	.019	1.3421	17.9325

Based on observed means.

*. The mean difference is significant at the .05 level.

B. Left Rectus Abdominis

gender	(I) surface	(J) surface	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Male	Down-Slope	Horizontal	-12.6027*	3.21126	.001	-20.6862	-4.5192
		Up-Slope	-6.8573	3.21126	.112	-14.9408	1.2262
	Horizontal	Down-Slope	12.6027*	3.21126	.001	4.5192	20.6862
		Up-Slope	5.7453	3.21126	.211	-2.3382	13.8288
	Up-Slope	Down-Slope	6.8573	3.21126	.112	-1.2262	14.9408
		Horizontal	-5.7453	3.21126	.211	-13.8288	2.3382
Female	Down-Slope	Horizontal	-4.5963	3.46344	.419	-13.2533	4.0608
		Up-Slope	-14.5301*	3.46344	.000	-23.1872	-5.8731
	Horizontal	Down-Slope	4.5963	3.46344	.419	-4.0608	13.2533
		Up-Slope	-9.9339*	3.46344	.020	-18.5909	-1.2768
	Up-Slope	Down-Slope	14.5301*	3.46344	.000	5.8731	23.1872
		Horizontal	9.9339*	3.46344	.020	1.2768	18.5909

Based on observed means.

*. The mean difference is significant at the .05 level.

Table 40. Post Hoc tests for right and left internal obliques.

A. Right Internal Oblique

gender	(I) surface	(J) surface	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Male	Down-Slope	Horizontal	-14.2707*	3.72105	.001	-23.6374	-4.9039
		Up-Slope	-8.3400	3.72105	.091	-17.7068	1.0268
	Horizontal	Down-Slope	14.2707*	3.72105	.001	4.9039	23.6374
		Up-Slope	5.9307	3.72105	.289	-3.4361	15.2974
	Up-Slope	Down-Slope	8.3400	3.72105	.091	-1.0268	17.7068
		Horizontal	-5.9307	3.72105	.289	-15.2974	3.4361
Female	Down-Slope	Horizontal	-5.6341	4.36905	.440	-16.5548	5.2866
		Up-Slope	-19.5712*	4.36905	.000	-30.4919	-8.6505
	Horizontal	Down-Slope	5.6341	4.36905	.440	-5.2866	16.5548
		Up-Slope	-13.9371*	4.36905	.009	-24.8578	-3.0164
	Up-Slope	Down-Slope	19.5712*	4.36905	.000	8.6505	30.4919
		Horizontal	13.9371*	4.36905	.009	3.0164	24.8578

Based on observed means.

*. The mean difference is significant at the .05 level.

B. Left Internal Oblique

gender	(I) surface	(J) surface	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Male	Down-Slope	Horizontal	-14.4560*	3.77805	.002	-23.9663	-4.9457
		Up-Slope	-8.5253	3.77805	.088	-18.0356	.9849
	Horizontal	Down-Slope	14.4560*	3.77805	.002	4.9457	23.9663
		Up-Slope	5.9307	3.77805	.300	-3.5796	15.4409
	Up-Slope	Down-Slope	8.5253	3.77805	.088	-.9849	18.0356
		Horizontal	-5.9307	3.77805	.300	-15.4409	3.5796
Female	Down-Slope	Horizontal	-5.6341	4.31419	.430	-16.4177	5.1495
		Up-Slope	-19.7195*	4.31419	.000	-30.5031	-8.9359
	Horizontal	Down-Slope	5.6341	4.31419	.430	-5.1495	16.4177
		Up-Slope	-14.0853*	4.31419	.007	-24.8689	-3.3017
	Up-Slope	Down-Slope	19.7195*	4.31419	.000	8.9359	30.5031
		Horizontal	14.0853*	4.31419	.007	3.3017	24.8689

Based on observed means.

*. The mean difference is significant at the .05 level.