Effect of Lateral Ankle Joint Anesthesia on Center of Balance, Postural Sway, and Joint Position Sense

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Hertel, J.N., Guskiewicz, K.M., Kahler, D.M., & Perrin, D.H. (1996). Effect of lateral ankle joint anesthesia, center of balance, postural sway, and joint position sense. Journal of Sport Rehabilitation, 2:111-119.

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Abstract:

The purpose of this study was to investigate the effects of induced anesthesia of the lateral ankle joint on proprioception as assessed in weight-bearing and nonweight-bearing conditions. Sixteen subjects were assessed under normal conditions and following an 8-cc injection of lidocaine into the anterior talofibular ligament of the ankle being tested. Center of balance and postural sway measurements were analyzed, revealing a significant lateral adjustment of center of balance during the stable tests compared to a medial adjustment during the dynamic tests under the anesthetized condition. ANOVA of postural sway scores revealed no main effect for condition (anesthesia vs. no anesthesia), but sway scores were higher during the two dynamic conditions as compared to the stable condition. ANOVA of joint position error scores revealed no main effect for condition. Findings suggest that inhibition of the joint receptor afferent fibers adversely affected joint proprioception as assessed while subjects were weight bearing but not while they were non—weight bearing.

Article:

Lateral ankle ligament sprains are one of the most common injuries incurred during athletics. The incidence of prolonged functional instability, or giving way of the ankle, following lateral ankle sprains has been reported to be between 31 and 35% (1, 10, 11, 17). Debate exists as to whether the functional instability is due primarily to proprioceptive deficits or mechanical instability (16, 18). Damage to joint proprioceptors has been suggested as the cause of functional instability following ligamentous injury. Freeman et al. (11) were the first to report a decrease in the frequency of functional instability following ankle sprains when coordination exercises were performed as part of rehabilitation. This finding has led to the inclusion of balance training in ankle rehabilitation programs (15).

Joint proprioceptors are believed to be damaged during injury to the lateral ligaments of the ankle because the joint receptor fibers possess less tensile strength than the ligament fibers (11). Damage to the joint receptors is believed to cause joint deafferentation. This diminishes the supply of messages from the injured joint up the afferent pathway and disrupts proprioceptive function (11).

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Nerve injury has been reported to be as high as 86 and 83% for the peroneal and posterior tibial nerves, respectively, following Grade III ankle sprains (24). Several studies have shown that lateral ankle sprains have adverse effects on ankle joint position sense (12, 13) and postural sway (6, 11, 12, 17, 21, 25). Contradictory findings indicating no significant loss of joint position sense (14) or postural sway (14, 27, 28) have also been reported. In addition, lateral ankle sprains have been shown to reduce peroneal muscle reaction time to lateral perturbation of the ankle (2, 18, 19, 23). Bullock-Saxton (3) also found decreased EMG responses of the ipsilateral gluteus maximus muscle, one of the primary postural stabilizer muscles, in subjects with severe unilateral ankle sprains.

Researchers in three studies (7, 9, 20) attempted to simulate joint deafferentation by injecting a local anesthetic into the ankle joint. Two studies (7, 20) found that postural sway did not increase with deafferentation of the ankle joint. Konradsen et al. (20) found that passive joint position sense decreased significantly following anesthesia. Feuerbach et al. (9) found a decreased ability to actively reposition the ankle following injection of a local anesthetic.

Weight-bearing or closed kinetic chain exercises have gained popularity in the rehabilitation of lower extremity joint injuries. A closed kinetic chain exists when the terminal segment of an extremity is fixed and a predictable pattern of joint movements occurs (4). An open kinetic chain is said to exist anytime the terminal segment is not fixed. One of the purported benefits of closed kinetic chain exercise is increased proprioceptive stimulation (4, 26), although there is a lack of scientific evidence to support this claim.

The purpose of this study was to determine if induced anesthesia of the lateral ankle joint affected proprioception assessed in weight-bearing and non-weightbearing conditions. Center of balance and postural sway were used as measurements of joint proprioception for the weight-bearing condition, while passive joint position sense was used as a measurement of joint proprioception for the nonweight-bearing condition.

MATERIALS AND METHODS

Subjects

Sixteen active individuals (8 males, 8 females, age = 22.6 ± 1.9 years, height = 172.1 ± 10.0 cm, weight = 69.7 ± 11.3 kg) volunteered to participate in this study. All subjects were free of previous injury to the tested lower extremity and were free of any vestibular lesions. Each subject read and signed a human consent form approved by a Medical School Human Investigation Committee.

Instrumentation and Procedures

Center of balance and postural sway were measured using a Chattecx Dynamic Balance System (Chattanooga Group, Hixson, TN). Passive joint position sense was measured using a KinCom isokinetic dynamometer (Chattanooga Group, Hixson, TN).

Subjects reported for testing on two separate occasions. They were randomly assigned to a counterbalanced schedule, which determined if the ankle was anesthetized during the first or second testing session and whether center of balance and postural sway or joint position sense was assessed first. Randomization and counterbalancing were implemented to help control for any learning effects.

The lateral aspect of the ankle was anesthetized using an 8-cc injection of 1% lidocaine, injected into the anterior talofibular ligament and lateral joint capsule. The peroneal tendons and sheaths were not injected. Anesthesia was considered sufficient 5 min following injection, at which time testing began. All injections were administered by the same orthopedic surgeon.

Each subject was assessed for center of balance and postural sway during unilateral stance while barefoot, with eyes closed and arms folded across the chest. Subjects were instructed to maintain their balance under one static and two dynamic conditions. One trial was conducted from a stable platform and two trials were conducted from a moving platform, the latter testing plantar flexion/dorsiflexion and inversion/eversion movements. Three 10-s trials were performed for each of the three conditions. Mean center of balance and mean postural sway for each condition were calculated.

The Chattecx Balance System measured vertical reaction forces using four force transducers placed under the medial and lateral aspects of the heel and forefoot. The angular perturbations of the device have a period of 8.33 s and are constructed as a sinusoidal from horizontal to 4° posterior tilt (dorsiflexion) and back to horizontal. The period can be varied from 0 to 8.3 s, and the subject can be tilted two additional ways: from horizontal to a plantar flexed position back to horizontal, or from 4° plantar flexion through 4° dorsiflexion and back to horizontal. The inversion/eversion condition was measured in the same manner but with the subject turned at a right angle from the plantar flexion/dorsiflexion position. Fluctuations in displacement of the center of balance reflected the amount of postural sway during the three independent platform conditions.

Center of balance is defined as the center point of vertical foot pressure throughout the 10-s trial. The center of balance measurements are expressed as points on an x-axis (medial/lateral) and y-axis (anterior/posterior) grid. Postural sway, as assessed by this device, is the distance expressed in centimeters that an individual travels away from his or her mean center of balance.

Mattacola and Perrin (22) investigated intertester reliability of the Chattecx Balance System during single-leg static and dynamic testing and reported intraclass correlation coefficients (and standard errors of measurement in centimeters) ranging from .41 (.21) to .90 (.06). Byl and Sinnott (5) investigated intratester and intertester reliability of the instrument and reported correlation coefficients of .92 and .90, respectively.

Passive joint position sense was measured with the subject barefoot, lying supine with the knee flexed to 90° and the ankle plantar flexed 10° and in subtalar neutral. The foot was secured to a foot plate that passively inverted and everted the foot at a speed of 3° per second. The subjects were tested with their eyes closed to eliminate any visual feedback. The foot was passively moved to one of three reference angles (10° eversion, 20° and 30° inversion) from the initial neutral position. The ankle was held at the test position for 15 s and was passively moved to the end range of motion and then returned toward the start position. The ankle was again stopped at the test position for 15 s and then returned to the start position. The ankle was then returned toward the reference angle, and the subject was instructed to provide resistance to the passive movement when he or she sensed that the ankle had replicated the reference angle. This force exceeded the dynamometer's preset minimal force, thus terminating movement and providing the dynamometer with a measurement of the reproduced angle. Data were collected in degrees of error from the reference angle. Three trials for each position were performed in a counterbalanced order, and mean scores of error were determined for each position.

Statistical Analysis

The SPSS Release 4.1 Statistical Package (SPSS Inc., Chicago) was used to analyze the data. Means of the three trials for each of the center of balance and postural sway tests were calculated for the normal and anesthetized conditions, as were the mean scores for joint position sense trials. A three-factor repeated-measures ANOVA on center of balance scores was run to determine the effect of anesthesia on center of balance with the variables being condition (anesthesia vs. no anesthesia), platform movement, and axis (x-axis to y- axis). A two-factor repeated-measures ANOVA was used to compare postural sway scores between the normal and anesthetized conditions. Ankle condition and platform movement were the within-subject variables. A two-factor repeated-measures ANOVA was used to compare the effects of anesthesia on joint position sense with ankle condition and reference angle as the within- subject variables. The level of significance was .05.

RESULTS

A three-factor ANOVA on center of balance scores revealed a main effect between the normal and anesthetized conditions, $F(1, 14) = 8.83$, $p < .05$. Tukey post hoc analysis revealed a significant lateral adjustment of center of balance during the static tests under anesthesia and a significant medial adjustment during the two dynamic conditions under anesthesia ($p < .05$). Center of balance scores under the normal and anesthetized conditions are presented in Figure 1. A movement by axis interaction, $F(2, 28) = 4.26$, $p < .05$, was also found. No main effects were found for platform movement, $F(2, 28) = .82$, $p > .05$, or axis (x axis to y axis), $F(1, 14) = .33$, $p > .05$. Table 1 illustrates the within-subjects effects.

Postural sway scores under the normal and anesthetized conditions are presented in Figure 2. A two-factor repeated-measures ANOVA on postural sway scores revealed no main effect between the normal and anesthetized conditions, $F(1, 14) = .95$, $p > .05$. Tukey post hoc analysis revealed that postural sway was significantly greater in the two dynamic conditions as compared to the static condition. There was no condition by movement interaction, $F(2, 28) = .11$, $p > .05$.

Joint position error scores for the normal and anesthetized conditions are presented in Figure 3. A two-factor repeated-measures ANOVA on joint position scores revealed no main effect between the normal and anesthetized conditions, $F(1, 15) = .12$, $p > .05$. A main effect was found for the scores at the different

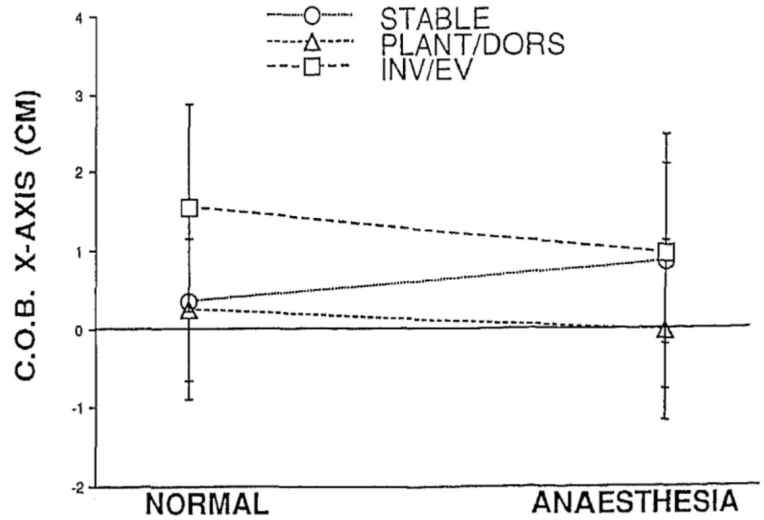

Figure 1— Center of balance measures (in centimeters) for the x-axis during three platform conditions and two treatment conditions. Positive x values represent a medial shift, while negative values represent a lateral shift.

Table 1 ANOVA Table for Center of Balance (Repeated Measures, Three Within- Subject Variables)

Sources of variance	*SS*	*DF*	*MS*	*F*	*p*
Within cells	40.99	28	1.46		
Movement	2.39	2	1.20	0.82	.452
Within cells	33.87	14	2.42		
Condition	21.36	1	21.36	8.83	.010*
Movement by condition	5.09	2	2.55	3.00	.066
Within cells	6.57	14	0.47		
Axis	0.15	1	0.15	0.33	.576
Axis by condition	9.38	1	9.38	3.52	.082
Axis by movement	8.18	2	4.09	4.26	.024*
Movement by condition by axis	1.73	2	0.86	0.97	.393

'Significant at $p < .05$.

reference angles, $F(2, 30) = 9.32$, $p < .05$. Tukey post hoc analysis revealed that scores for the tests at 10° eversion were significantly lower than scores for either of the inversion angles ($p < .05$). No condition by angle interaction was found, $F(2, 30) = .37$, $p > .05$.

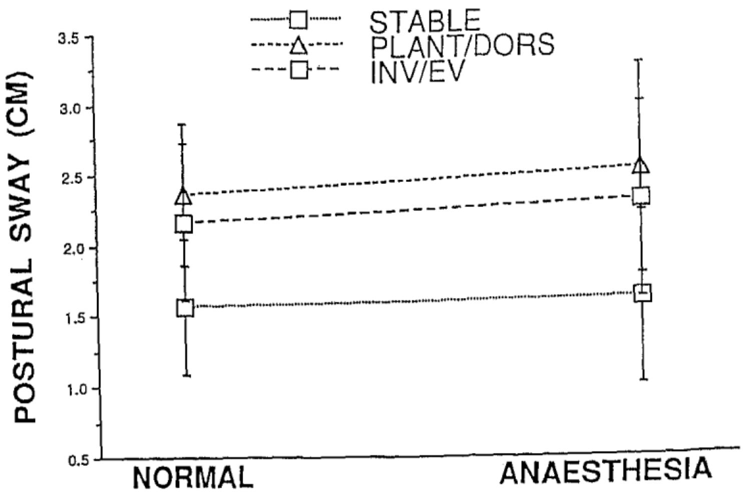

Figure 2 —Postural sway measures (sway index in centimeters) during three platform conditions and two treatment conditions.

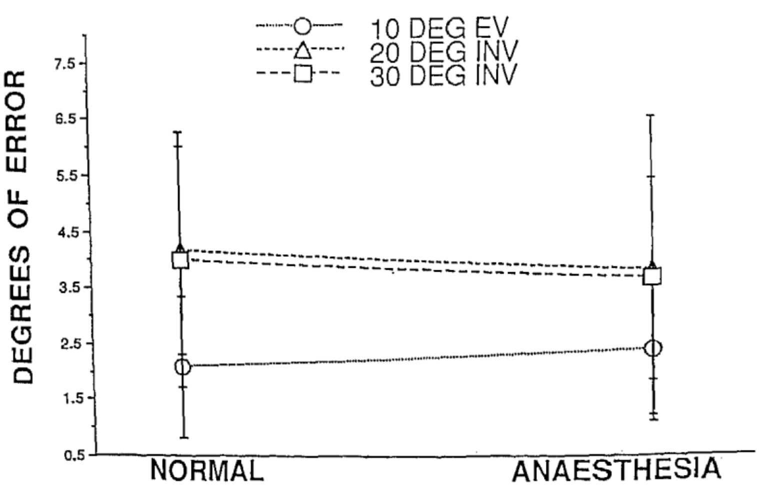

Figure 3 — Passive joint position error scores during three angle conditions and two treatment conditions.

Discussion

Lateral ankle joint anesthesia does not appear to alter postural sway or passive joint position sense but does affect the center of balance in both static and dynamic single- leg stance. This suggests the presence of an adaptive mechanism to compensate for the loss of afferent stimuli from the region of the lateral ankle ligaments.

Alteration of center of balance as an adaptive mechanism has not been previously examined in the literature. The subjects in this study demonstrated a significant shift in the measured center of balance primarily in the medial and lateral directions rather than the anterior and posterior directions. Subjects may adjust their center of balance to compensate for loss of proprioceptive input in the anesthetized state. It is not clear why subjects shift their center of balance laterally in the static anesthetized condition and medially in the dynamic anesthetized condition, It is possible that shifting the center of balance provides additional proprioceptive input from cutaneous receptors in the sole of the foot and/or stretch receptors in the peroneal muscle/tendon unit. This would seem to support the use of proprioceptive exercises in the closed kinetic chain during rehabilitation of ankle sprains.

Balance is maintained by contributions from the visual, proprioceptive, and vestibular systems. Our study attempted to isolate the proprioceptive contributions to balance. Visual contribution was eliminated by having subjects perform all tests with the eyes closed. Most investigators agree that the vestibular system is primarily involved in the stabilization of slow body sway, which is achieved by a very low level of leg activation (8). Healthy people normally rely more on visual and proprioceptive input to control body sway (8). Slow body sway was not isolated in this study because the unilateral stance and moving platforms caused higher levels of leg activation, thus limiting the vestibular contribution and heightening the proprioceptive contribution.

Our results indicate no increase in postural sway following deafferentation of the lateral ankle joint. These results support the findings of DeCarlo and Talbot (7) and Konradsen et al. (20), who also injected the ankle joint with an anesthetic and found no increase in postural sway. Our results also support studies by Tropp at al, (27, 28), who found no increases in postural sway among soccer players with ankle injuries. However, Tropp et al. (28) did report that uninjured soccer players with sway scores more than two standard deviations above the mean were more likely to suffer a future ankle sprain than those players with sway scores closer to the mean.

The current findings contradict other studies that reported increased postural sway in injured subjects (11, 12, 16, 21, 25), although all but one of these studies (25) used the modified Rhomberg test as a subjective assessment of sway. The modified Rhomberg test was performed by having the subject assume a single-leg stance with eyes open and then closed. Examiners determined the amount of instability by observing sway of the injured and uninjured legs and comparing the two. Tests were considered positive if either the examiner or the subject considered stance on the injured leg less stable than stance on the uninjured leg.

All of the studies that used the modified Rhomberg test found increases in instability (11, 12, 16, 21), while those that used instrumentation to quantify postural sway did not find significant decreases among injured or anesthetized groups (7, 20, 27, 28), with the exception of Orteza et al. (25). It should be noted that the researchers who attempted to quantify postural sway used trials of 10 to 60 s in length, while those subjectively observing only did so until the subject returned to a bilateral stance. It should be expected that an inability to balance could increase an athlete's susceptibility to a recurrent ankle sprain. However, ankle sprains occur in the brief moments between heelstrike and midstance, so the loss of balance must occur within these finite phases of gait. Perhaps assessment of postural sway over the course of 10 to 60 s is an invalid predictor of balance and joint proprioception during functional activities. Further research needs to examine postural sway
during brief periods of time such as the first seconds after movement of the platform. Current software on the Chattecx Dynamic Balance System does not permit the recording of these data.

Our results show increased postural sway during platform movement as opposed to stable platform conditions. This is to be expected, as movement of the platform forces a change in the muscles used to maintain balance. Several studies (2, 4, 16, 18, 19, 23) have examined peroneal muscle reaction time and EMG activity during lateral perturbations of the ankle joint in subjects following ankle sprains. Brunt et al. (2) found longer reaction time to sudden inversion among the peroneus longus, posterior tibialis, and anterior tibialis muscles in subjects 1 year after suffering a severe ankle sprain. These results are supported by similar studies finding delayed reaction of the peroneus longus and brevis muscles in injured subjects (18, 19, 23) but are not consistent with findings of Isakov et al. (16) and Konradsen et al. (20). Muscle reaction time may be a better assessment of joint proprioception in the closed kinetic chain as it accounts for both detection of movement and reflex reaction time. Muscle reaction time may also be a more functional assessment of the effects of joint deafferentation.

The lack of change in passive joint position sense scores between the normal and anesthetized conditions is not consistent with the findings of Konradsen at al. (20) and Gam and Newton (12). Konradsen et al. (20) found a significant increase in the amount of error in sensing passive joint position following injection of the ankle joint, while Gam and Newton (12) found a decrease in the sense of passive movement in subjects with recurrent ankle sprains. Our results agree with those of Gross (14), who found no significant differences in passive joint position sense of subjects with ankle injuries. The findings in the present study and those of Gross (14) suggest that non-weight-bearing position sense is not affected by diminished afferent input from the lateral ankle, whether caused by anesthesia or by injury.

Further investigation will be necessary to determine the effects of joint deafferentation and altered center of balance on functional performance. It is not yet clear whether the center of balance adaptations seen in this study also occur in athletes with injuries to the lateral ankle ligaments. It is possible that interventions such as orthotic fitting and proprioceptive rehabilitation may alter the adaptive responses seen in this study.

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