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Visual Disruption and Neuromechanics During Landing-Cutting in Individuals With Chronic Ankle Instability

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Context: Individuals with chronic ankle instability (CAI) demonstrate altered movement patterns when their vision is disturbed during simple tasks, such as single-legged standing and walking. However, it remains unclear whether visual disruption by stroboscopic glasses alters movement patterns during landing-cutting movements, considered highly demanding sport maneuvers that mimic a typical athletic movement.

Objectives: To identify altered lower extremity kinematics and muscle activation when vision is disrupted by stroboscopic glasses during landing-cutting tasks in individuals with CAI.

Design: Case-control study.

Setting: Laboratory.

Patients or Other Participants: A total of 18 individuals with CAI (age = 22.3 ± 2.3 years, height = 1.75 ± 0.1 m, mass = 72.5 ± 9.8 kg) and 18 matched healthy controls (age = 21.7 ± 2.3 years, height = 1.75 ± 0.1 m, mass = 71.9 ± 10.3 kg).

Intervention(s): All participants performed 5 trials of a landing-cutting task with (SV) and without (NSV) stroboscopic glasses.

Main Outcome Measure(s): Frontal- and sagittal-plane lower extremity kinematics and 6 lower extremity muscle activations during the stance phase of a landing-cutting task in the SV and NSV conditions.

Results: Individuals with CAI demonstrated more ankle-inversion angle from 18% to 22% and from 60% to 100% of the stance phase and more peroneus longus activation from initial contact to 18% of the stance phase under the SV condition than under the NSV condition. We observed no differences in knee- and hip-joint angles between the visual conditions for both groups.

Conclusions: When wearing stroboscopic glasses, individuals with CAI showed altered movement patterns, including increased ankle-inversion angle and peroneus longus activation during the stance phase of a landing-cutting task. The results suggest that they may lack the ability to reweight sensory information to adapt their movement to visual disruption.

Key Words: stroboscopic glasses, ankle sprains, visual reliance

Key Points

- Stroboscopic glasses can be used as visual disruption devices while individuals perform functional movements, which may more closely simulate the neurocognitive demands of daily living and sporting activities.
- Individuals with chronic ankle instability tend to rely more on visual information than healthy control individuals during a landing-cutting task.
- Stroboscopic glasses can be used during rehabilitative training to decrease visual reliance and upregulate reliance on somatosensory information for motor programming.

More than 23 000 lateral ankle sprains (LASs) occur in the United States each day, with an approximate cost of $1000 per injury.[1] An LAS represents one of the most frequent musculoskeletal injuries during sport-related movements.[2] Approximately 70% of people who experience an LAS subsequently develop chronic ankle instability (CAI), which is characterized by recurrent LASs with swelling, pain, and loss of function as well as episodes of "giving way."[3] This is thought to result from pathomechanical (eg, pathologic laxity and arthrokinematics restrictions), sensory-perceptual (eg, perceived instability and kinesiophobia), and motor-behavioral (eg, altered reflexes and neuromuscular inhibition) impairments.[3] These impairments can also have long-term health consequences for cartilage, such as osteoarthritis, thereby decreasing the quality of life.[4]

Altered movement patterns in those with CAI have been widely reported in previous studies during various activities such as walking, a single-legged drop landing, and a landing-cutting task.[5–7] During walking, individuals with CAI have demonstrated increased plantar flexion and decreased eversion angles compared with healthy control individuals, which is believed to increase susceptibility to LASs.[5] During a single-legged drop landing and a landing-cutting task, individuals with CAI have shown protective movement patterns, defined by greater dorsiflexion and eversion angles than healthy control individuals and copers.[6,7] Furthermore, individuals with CAI have also displayed a hip-dominant strategy by increasing hip-extension moment and power and hip-flexion angle during landing and jumping and single-legged drop landings.[8,9] Overall, individuals with CAI seem to show protective movement patterns by decreasing ankle movements and increasing hip movements during demanding activities such as landing-cutting tasks. By contrast, they demonstrate injurious ankle positions during relatively less demanding tasks, such as walking. Thus, lower extremity movement patterns in individuals with CAI may depend on the demands or difficulty of movement tasks.[6]

When sport activities impose constraints that increase visual or cognitive loading or difficulty of motions, individuals with preexisting ligamentous injury (eg, LAS or anterior cruciate ligament tear) may have less capability to manage these constraints, resulting in injurious movements that lead to subsequent reinjury.[10] As such, researchers have tried to apply additional demands by combining visual or cognitive loading during movements in individuals with CAI. Researchers have reported that individuals with CAI showed greater ankle inversion and dorsiflexion and stride-time variability than healthy controls when they were instructed to subtract serial numbers, defined as cognitive loading, during walking.[11,12] Other than cognitive loading, authors of other previous studies used visual disruption to investigate if individuals with CAI demonstrate altered movement patterns.[13,14] Terada et al reported no differences in movement patterns whether visual focus was altered or not in individuals with CAI during a single-legged drop landing.[13] By contrast, Han et al reported that, when vision was disturbed by stroboscopic glasses, individuals with CAI demonstrated decreased postural control relative to copers and healthy control individuals.[14] Overall, individuals with CAI seem to demonstrate altered movement patterns when their vision or cognition is disturbed during simple tasks such as single-legged standing and walking. However, it remains unclear whether visual disruption by stroboscopic glasses alters movement patterns during landing-cutting movements, which are considered highly demanding sport maneuvers that mimic a typical athletic movement and are potentially associated with LASs.[15]

We assume that visual disruption induced by stroboscopic glasses would compel the central nervous system to adopt an adaptive strategy, potentially increasing the weighting of the remaining proprioceptive inputs.[16] This adjustment may result in distinct movement patterns during demanding sport maneuvers. Stroboscopic glasses alter postural control and movement patterns (eg, single-legged drop) in individuals with CAI who are believed to demonstrate greater visual reliance as they reweight more reliable sensory information (eg, vision or vestibular information or both) instead of relying on altered afferent information from the injured ankle joint.[14,17,18] Thus, we used stroboscopic glasses to identify how individuals with CAI perform demanding sports maneuvers when the glasses disrupt their most reliable sensory information.

The purpose of our study was to identify altered lower extremity kinematics and muscle activation when vision is disrupted by stroboscopic glasses during the stance phase of landing-cutting motion in individuals with CAI compared with matched healthy control individuals. We hypothesized that movement patterns and muscle activation would be different with and without stroboscopic glasses in individuals with CAI but not in healthy control individuals.

Table 1. Participant Characteristics

Characteristic	Chronic Ankle Instability Group (n = 18)	Control Group (n = 18)	t_{34} Value	P Value
	No.			
Sex				
Male	10	10	NA	NA
Female	8	8	NA	NA
	Mean ± SD			
Age, y	22.3 ± 2.3	21.7 ± 2.3	−0.82	.42
Mass, kg	72.5 ± 9.8	71.9 ± 10.3	−0.17	.87
Height, m	1.75 ± 0.1	1.75 ± 0.1	−0.34	.74
Body mass index, kg/m^2	23.5 ± 2.2	23.5 ± 2.6	0.05	.96
FAAM-ADL, %	86.7 ± 2.9	100 ± 0.0	NA	NA
FAAM-Sports, %	75.1 ± 6.1	100 ± 0.0	NA	NA
Ankle Instability Instrument	6.1 ± 1.1	0.0 ± 0.0	NA	NA

Abbreviations: ADL, Activities of Daily Living; FAAM, Foot and Ankle Ability Measure; NA, not applicable.

METHODS

Design

We conducted a case-control study in a laboratory setting with the independent variable of group (CAI and control). The dependent variables included frontal- and sagittal-plane lower extremity kinematics, along with the activation of 6 lower extremity muscles (tibialis anterior [TA], peroneus longus [PL], medial gastrocnemius [MG], vastus lateralis [VL], gluteus medius [Gmed], and gluteus maximus [Gmax]) during the stance phase of a landing-cutting task, both with and without stroboscopic glasses.

Thirty-six physically active men and nonpregnant women, including 18 individuals with CAI and 18 matched healthy controls, were recruited from a university population (Table 1). We considered sample size a priori (G*Power version 3.1.5; Heinrich-Heine-Universität Düsseldorf) from several different lower extremity kinematics and electromyography (EMG) activations from previous similar study data.[7] Considering α, β, and Cohen d values of .05, 0.2, and 0.69, respectively, we defined a sample size of 18 participants in each group. We followed the International Ankle Consortium's guidelines to recruit qualified individuals with CAI.[19] Inclusion criteria for each group are presented in Table 2. All participants provided written informed consent, and the study was approved by the Institutional Review Board of Brigham Young University.

The experimental procedures are illustrated in Figure 1. All participants wore spandex shorts and short-sleeved shirts that we provided. We placed 44 reflective markers over anatomic landmarks as previously described.[20] Surface EMG electrodes with an adhesive interface (Delsys)

Table 2. Specific Inclusion Criteria for Each Group

Group	Inclusion Criteria
Chronic ankle instability	1. Greater than or equal to 2 acute lateral ankle sprains requiring immobilization and/or nonweight bearing for ≥3 d, external supports for ≥7 d, or both 2. History of at least 2 episodes of "giving way" within the past 6 mo 3. FAAM-ADL of <90% 4. FAAM-Sports of <80% 5. Greater than or equal to 5 *yes* answers on the Ankle Instability Instrument 6. No lower extremity surgery or fracture 7. Physical activity ≥3 d/wk for 90 min within the past 3 mo
Control	1. No history of previous lateral ankle sprain 2. FAAM-ADL of 100% 3. FAAM-Sports of 100% 4. No *yes* answers on the Ankle Instability Instrument 5. Physical activity ≥3 d/wk for 90 min within the past 3 mo

Abbreviations: ADL, Activities of Daily Living; FAAM, Foot and Ankle Ability Measure.

were placed on 6 different muscles including the TA, PL, MG, VL, Gmed, and Gmax, based on the Surface ElectroMyoGraphy for Non-Invasive Assessment of Muscles recommendations.[20] Rectangular electrodes (27 × 37 × 13 mm) were made of 99% silver contact material with a 4-bar formation. The input impedance was <60 kΩ, and the common mode rejection ratio was <80 dB. We did not use any reference electrodes. The skin was shaved, scrubbed, and cleansed with 70% isopropyl alcohol to reduce local impedance over the electrode placement. The interelectrode spacing was 10 mm. The EMG and kinematic data were synchronized using Visual 3D (C-Motion) software.

After performing up to 10 practice trials of a landing-cutting task onto a force plate (1000 Hz; AMTI), participants performed 5 trials of the task with (SV) and without (NSV) stroboscopic glasses, for a total of 10 trials. For the SV condition, we used stroboscopic glasses (Senaptec) at 3 Hz (strobe rate level 4: 0.1 s of clear and 0.233 s of opaque). The order of the visual condition, SV or NSV, was randomized but counterbalanced using JMP Pro 13 (SAS Institute, Inc). The landing-cutting task comprised 3 components: (1) a maximal 2-footed vertical jump from a starting mark located at 50% of the participant's height from the center of the force plate (landing mark 1), (2) landing on the involved limb, and (3) an immediate 90° side-cut to the contralateral side at a distance (landing mark 2) that was 65% of the participant's height.[21] The 3 target locations (starting and landing marks 1 and 2) were marked to ensure consistency across all trials for each participant. In each trial, we orally encouraged participants to use maximal effort (eg, "jump as high as you can and cut as quickly as possible").

Motion data during the landing-cutting task were collected using 12 high-speed cameras (250 Hz; Qualisys). Spatial trajectories from the reflective markers were measured using Qualisys software and imported into Visual 3D. The trajectories were smoothed using a fourth-order, low-pass Butterworth filter (10 Hz) based on a previous similar study.[20] A 3-dimensional lower extremity model was created using previously described methods.[22] This model was used to calculate 3-dimensional ankle-, knee-, and hip-joint angles with 95% CIs. Dependent variables were analyzed and normalized to 100% of the *stance phase*, which was defined as the period from initial contact to toe-off with a 25-N vertical ground reaction force threshold.

We collected EMG data at 2000 Hz and synchronized them with motion data. The EMG amplitudes from 3

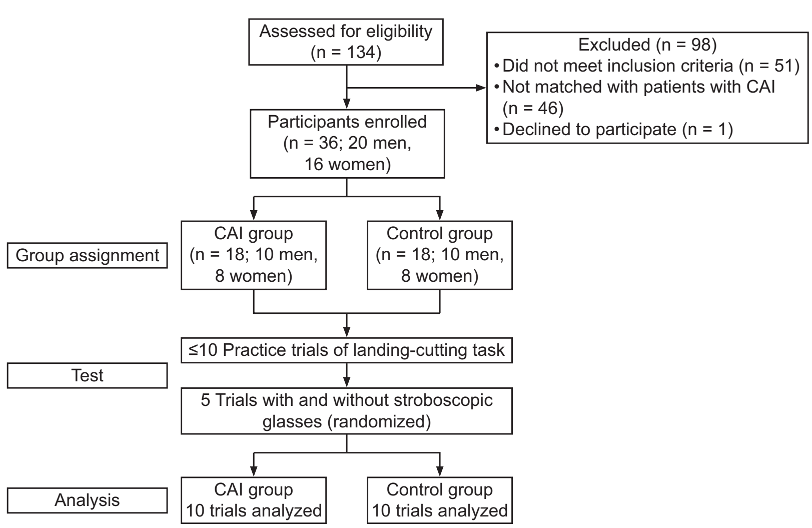

Figure 1. Study flowchart. Abbreviation: CAI, chronic ankle instability.

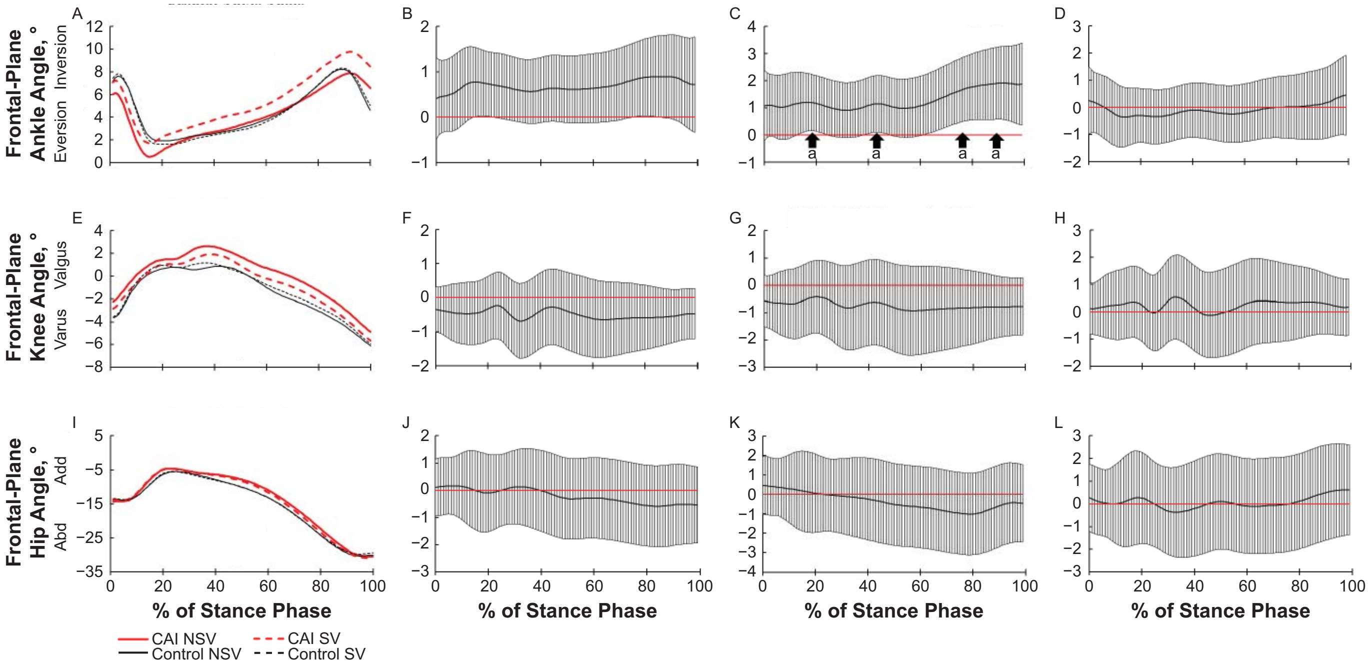

Figure 2. Frontal-plane lower extremity kinematics for the stance phase of landing-cutting. Ankle angle by group (A) and group-by-condition interaction (B) and differences between the landing-cutting task without stroboscopic glasses (NSV) condition and the landing-cutting task with stroboscopic glasses (SV) condition in the chronic ankle instability (CAI) group (C) and control group (D). Knee angle by group (E) and group-by-condition interaction (F) and differences between the NSV and SV conditions in the CAI group (G) and control group (H). Hip angle by group (I) and group-by-condition interaction (J) and differences between the NSV and SV conditions in the CAI group (K) and control group (L). Where 95% CIs (shaded gray area) do not cross 0, between-condition comparisons are different. Abbreviations: Abd, abduction; Add, adduction. [a] More inversion under the SV condition.

seconds of a quiet standing position were used as the reference values for normalizing EMG data.[23] The EMG amplitudes were then zeroed to baseline, rectified, and band-pass filtered (10–500 Hz).[23] We used a quiet stance to normalize EMG amplitudes because it provides the most stable and consistent reference values.[23] Furthermore, any change in EMG amplitude normalized to a quiet stance indicates a true increase or decrease in the neural drive. This approach led us to believe that normalizing our EMG amplitudes to a quiet stance would be appropriate.[24]

Functional data analyses were used to observe the entire curve of the stance phase during the landing-cutting task. This analysis was used to compare variables as polynomial functions rather than discrete values, thereby allowing us to evaluate entire movement curves during the period of interest. Using this statistical approach, we evaluated differences between 2 different visual conditions (SV and NSV) for ankle, knee, and hip kinematics and EMG activation during the stance phase of the landing-cutting task in the 2 groups (CAI and healthy control). We plotted the estimates of pairwise comparison functions between groups and visual conditions and 95% CIs to determine differences. If 95% CIs consistently intersected 0 in group-by-condition interaction graphs, we concluded that no differences existed, even if the 95% CI did not cross 0 in pairwise comparison graphs. Conversely, if 95% CIs did not cross 0 at any time in interaction graphs, we deemed differences to be present in pairwise comparisons, even if the timing of these differences varied between the interaction and pairwise comparison graphs. All functional data analyses were implemented using the fda package in a statistical program (version 1.2.5033; RStudio). Independent-samples *t* tests were used to compare participant characteristics between groups. The α level was set at .05.

RESULTS

We observed no difference in characteristics (eg, age, height, and mass) between groups (Table 1). We did not perform statistical analyses for the patient-reported outcomes, such as the Foot and Ankle Ability Measure (Activities of Daily Living and Sports subscales) and the Ankle Instability Instrument, as these outcomes were expected to differ between groups as a qualification criterion for study participation.

Figure 2 shows lower extremity kinematics in the frontal plane. A group-by-condition interaction ($P < .05$) was found from 18% to 23% and from 79% to 84% of the stance phase during the landing-cutting task in the frontal-plane ankle angle. The CAI group demonstrated up to 2° more ankle-inversion angle (80% change) from 18% to 22% and up to 3.3° more ankle-inversion angle (30% change) from 60% to 100% of the stance phase in the SV condition than in the NSV condition. However, we found no difference in the frontal-plane ankle angle between conditions in the control group. No group-by-condition interactions were found in the frontal-plane knee and hip angles for either group.

Figure 3 shows lower extremity kinematics in the sagittal plane. We observed no group-by-condition interactions in the sagittal-plane ankle, knee, and hip angles for either group.

Figure 4 shows EMG activation for 6 muscles in the lower extremity. A group-by-condition interaction ($P < .05$)

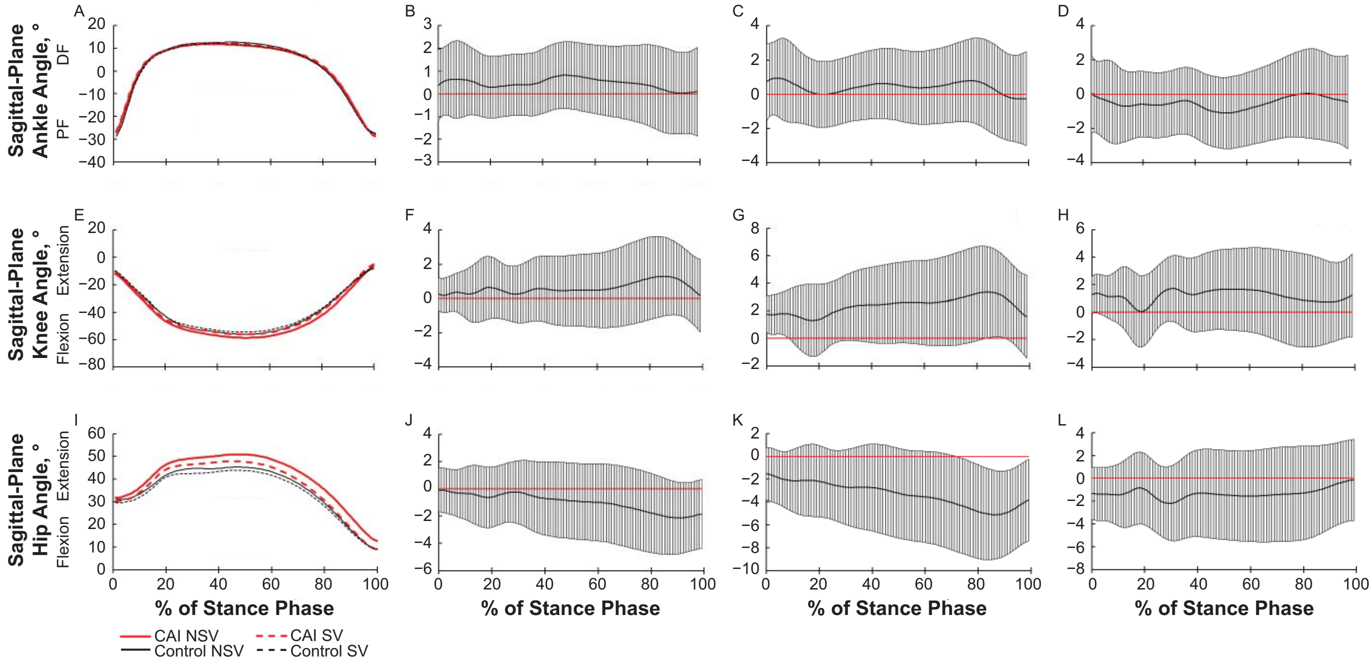

Figure 3. Sagittal-plane lower extremity kinematics for the stance phase of landing-cutting. Ankle angle by group (A) and group-by-condition interaction (B) and differences between the landing-cutting task without stroboscopic glasses (NSV) condition and the landing-cutting task with stroboscopic glasses (SV) condition in the chronic ankle instability (CAI) group (C) and the control group (D). Knee angle by group (E) and group-by-condition interaction (F) and differences between the NSV and SV conditions in the CAI group (G) and the control group (H). Hip angle by group (I) and group-by-condition interaction (J) and differences between the NSV and SV conditions in the CAI group (K) and control group (L). Where 95% CIs (shaded gray area) do not cross 0, between-condition comparisons are different. Abbreviations: DF, dorsiflexion; PF, plantar flexion.

was found from initial contact to 15% of the stance phase during the landing-cutting task in the PL. The CAI group showed up to 18% of reference value more PL activation (25% change) from initial contact to 18% of the stance phase in the SV condition than in the NSV condition. However, no difference was present in PL activation between conditions in the control group. We observed no group-by-condition interactions in the TA, MG, VL, Gmed, and Gmax.

DISCUSSION

The purpose of our study was to investigate how individuals with CAI demonstrate landing-cutting movements compared with matched healthy control individuals when their vision is disrupted by stroboscopic glasses. The primary finding of this study was that individuals with CAI displayed greater ankle-inversion angle in the stance phase of the landing-cutting task in the SV condition than in the NSV condition. However, the control group did not show any differences in lower extremity kinematics and muscle activation between the 2 visual conditions. In other words, visual disruption induced by stroboscopic glasses influenced neuromechanics during the landing-cutting task only for individuals with CAI, suggesting that they have less ability to reweight sensory information when vision is disrupted. When ≥ 1 sensory information sources are altered, the central nervous system can shift its reliance to more reliable information sources to stabilize posture; this process is defined as *sensory reweighting*.[25]

As we hypothesized, only individuals with CAI showed different movement patterns during the landing-cutting task when their vision was distorted by stroboscopic glasses. Specifically, individuals with CAI showed more ankle-inversion angle during the weight-acceptance (from 18% to 22%) and propulsion (from 60% to 100%) phases of the stance phase in the SV condition than in the NSV condition (Figure 2). Altered movement patterns due to visual disruption induced by stroboscopic glasses have frequently been reported in the literature for people with musculoskeletal injuries.[14,26] Grooms et al reported that patients with anterior cruciate ligament reconstruction had more knee sagittal- and frontal-plane excursion in the SV condition than in the NSV condition.[27] Han et al reported that individuals with CAI demonstrated worse dynamic postural control while wearing stroboscopic glasses, whereas LAS copers and healthy control individuals did not.[14] Even though these previous studies had different populations or tasks, our results are aligned with their observations. The mechanisms behind these alterations are still unknown. However, based on both our results and the previous findings, we could speculate 2 mechanisms. First, individuals with CAI may have less ability to reweight other sensory inputs to compensate for decreased visual information.[14] Increased visual reliance after multiple LASs could lead to constraints in dynamic sensory reweighting when visual information is limited. Second, the impaired somatosensory systems of individuals with CAI could inhibit efficient and safe movement patterns when visual information is limited.[3] To our knowledge, we are the first to examine altered neuromechanics due to visual disruption induced by stroboscopic glasses in individuals with CAI. Therefore, additional studies are needed to clarify or strengthen the suggested ideas.

Altered ankle-inversion angle in individuals with CAI during various movements has been widely reported in the

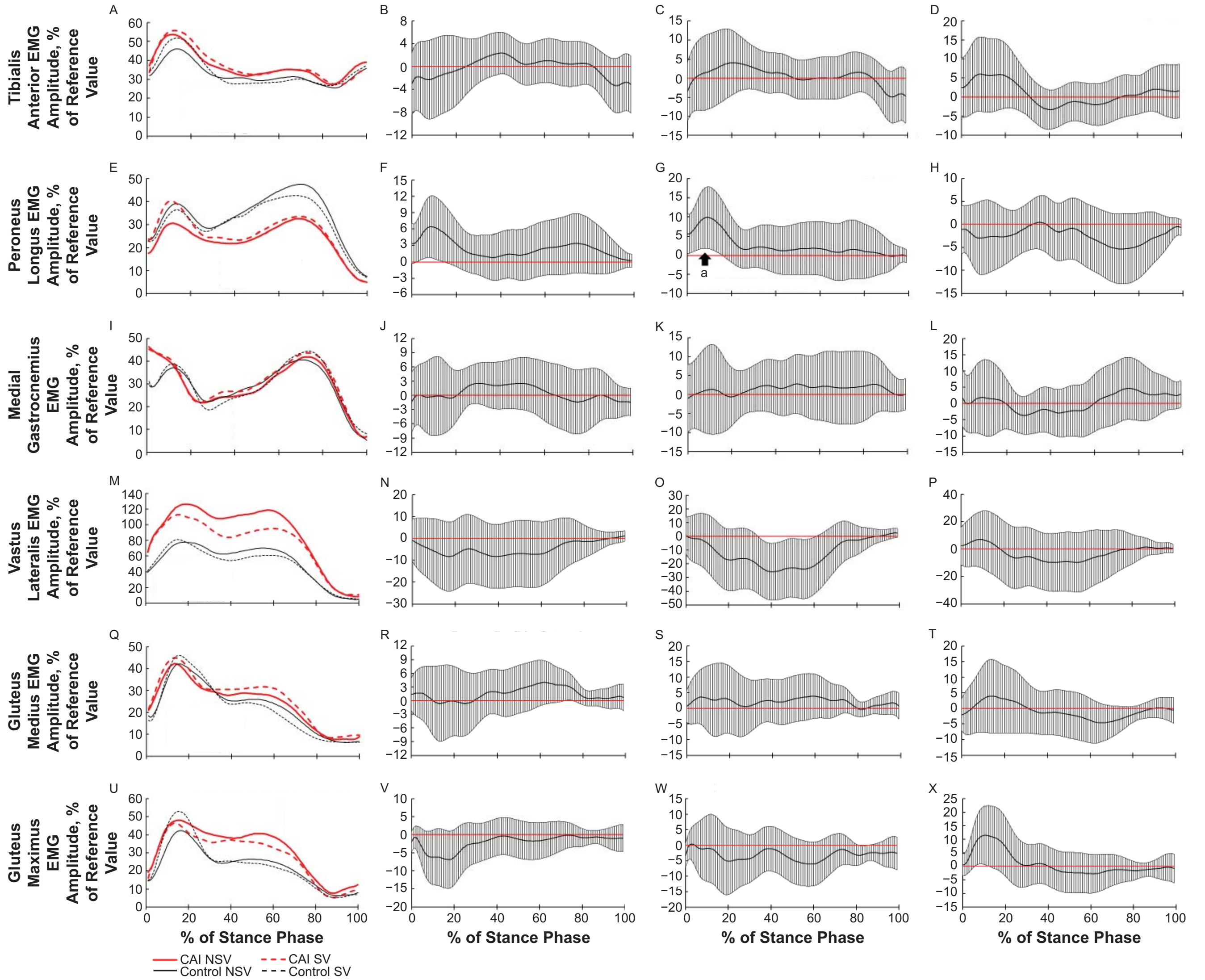

Figure 4. Lower extremity electromyography (EMG) activation of 8 muscles for the stance phase of landing-cutting. Tibialis anterior activation by group (A) and group-by-condition interaction (B) and differences between the landing-cutting task without stroboscopic glasses (NSV) condition and the landing-cutting task with stroboscopic glasses (SV) condition in the chronic ankle instability (CAI) group (C) and control group (D). Peroneus longus activation by group (E) and group-by-condition interaction (F) and differences between the NSV and SV conditions in the CAI group (G) and control group (H). Medial gastrocnemius activation by group (I) and group-by-condition interaction (J) and differences between the NSV and SV conditions in the CAI group (K) and control group (L). Vastus lateralis activation by group (M) and group-by-condition interaction (N) and differences between the NSV and SV conditions in the CAI group (O) and control group (P). Gluteus medius activation by group (Q) and group-by-condition interaction (R) and differences between the NSV and SV conditions in the CAI group (S) and control group (T). Gluteus maximus activation by group (U) and group-by-condition interaction (V) and differences between the NSV and SV conditions in the CAI group (W) and the control group (X). When 95% CIs (shaded gray area) do not cross 0, between-condition comparisons are different. [a] More peroneus longus activation under the SV condition.

literature. Researchers have reported that individuals with CAI show increased ankle-inversion angle during the stance phase of walking, which has been identified as a risk factor for recurrent ankle sprains in individuals with CAI.[5,28] Interestingly, on the other hand, when they perform more demanding tasks, such as a landing-cutting task, individuals with CAI seem to exhibit protective movement patterns with increased ankle eversion and dorsiflexion.[7] In our study, regardless of condition, individuals with CAI also demonstrated more ankle-eversion angle in the early stance phase of the landing-cutting task (from 0% to 18%) than healthy control individuals, which supports the findings of previous studies.[5,7] However, at the end of the stance phase (from 93% to 100%), individuals with CAI showed more ankle-inversion angle than healthy control individuals. The increased ankle-inversion angle at the end of the stance phase could be preceded by an increment of ankle-inversion angle when individuals with CAI performed the task in the SV condition. Thus, the use of stroboscopic glasses could convert protective movement patterns that individuals with CAI display into more injurious movement patterns, especially in the frontal plane, during landing-cutting tasks. In other words, a preplanned protective mechanism, more ankle eversion, is disrupted by lack of visual information in individuals with CAI.

In our study, individuals with CAI demonstrated greater PL activation in the early phase of the landing-cutting task (from 0% to 18%) in the SV condition than in the NSV condition. The peroneal musculature plays a critical role in controlling the amount of inversion at the ankle joint, thus providing protection against excessive inversion and injury.[29] Considering this, the increased PL activation might be attributed to an attempt to prepare for a safe landing when visual information is disturbed. However, our results showed that this effort did not lead to a reduction in the ankle-inversion angle during the same timeframe. In other words, when vision was partially blocked, individuals with CAI increased PL activation to land safely, but this did not alter the ankle-inversion angle. Furthermore, aside from the early phase, individuals with CAI consistently exhibited lower PL activation than the control group. This observation suggests that immediate effects of stroboscopic glasses on muscle activation may be minimal. Future studies are needed to determine whether (1) the use of stroboscopic glasses stimulates muscle activation in different movements and (2) neuromuscular training with stroboscopic glasses could improve muscle activation during dynamic movements such as landing-cutting movements.

We observed no group-by-condition interactions in knee and hip kinematics and muscle activations. We expected individuals with CAI to exhibit altered proximal neuromechanics in the SV condition because proximal alterations during landing tasks in individuals with CAI have been widely reported in the literature.[30] However, in our study, stroboscopic glasses affected neither knee and hip angles nor quadriceps and gluteus muscle activations during the landing-cutting task. The observed kinematic differences between the ankle joint and the proximal joints may explain why individuals with CAI might not be able to demonstrate adaptive neuromechanics in the ankle joint as much as in the knee and hip joints. Kim et al reported that individuals with CAI showed proximal adaptation with increased knee- and hip-joint kinetics to compensate for an unreliable sensorimotor system in the ankle joint during a landing-cutting task.[8] In that sense, we speculate that the presence of sensorimotor deficits in the ankle joint created this difference for knee and hip joints in people with a relatively reliable sensorimotor system. However, the mechanisms behind this are largely unknown. Therefore, future studies are needed to clarify this assumption.

Our findings relating to altered landing neuromechanics in the SV condition in individuals with CAI could provide useful insights for clinicians in 2 ways. First, stroboscopic glasses can be used as visual disruption devices while individuals perform functional movements, which may more closely simulate the neurocognitive demands of daily living and sporting activities than complete obstruction of vision. As we analyze altered dynamic movements induced by stroboscopic glasses, we may be able to learn how much people rely on vision during movement.[26] For instance, stroboscopic glasses can be used in athletes who have experienced LASs during sport-specific movements. We can then assess how the glasses modify their movement patterns compared with when they do not wear them, providing valuable insights into the extent to which athletes depend on their visual input. In this study, we were able to identify that individuals with CAI showed greater visual reliance during the landing-cutting task as their movement patterns were changed with the SV condition. High reliance on visual input caused by sensory reweighting due to an impaired somatosensory system in individuals with CAI has been widely reported in the literature and considered as a potential contributing factor for recurrent LASs.[31,32] Therefore, we suggest that clinicians identify visual reliance in various movements by having individuals with CAI wear stroboscopic glasses. Second, stroboscopic glasses can be used in training and rehabilitation programs to decrease visual reliance and upregulate reliance on somatosensory information for motor programming.[33] Stroboscopic glasses have been used in the training regimens of various sports, including baseball and ice hockey.[34,35] In previous studies, researchers reported the effectiveness of sport vision training with stroboscopic glasses in improving athletes' capabilities of using limited visual information and being sensitive to other sources of sensory information involved in skill execution, which resulted in improved performance after training after removing the glasses.[35] The current and previous findings collectively suggest that upregulation of the somatosensory system, coupled with the reduction of visual input through stroboscopic vision training, is imperative for enhancing sports performance, particularly in individuals with CAI.

Our study had several limitations. First, the findings can be generalized only to a physically active and college-aged population. Second, given the limitation of a cross-sectional study, it remains unclear whether individuals with CAI were already sensitive to visual disruptions during dynamic movements before their LASs or whether the LASs caused the alterations. Third, we used a quiet stance as a reference value for normalizing EMG amplitudes because of its stability and consistency. However, it may not fully represent our primary movement test, landing and cutting, potentially affecting our EMG results. Fourth, our exclusion criteria did not include a history of concussion or impaired vestibular system, which could potentially affect vestibular involvement, proprioceptive feedback, or both. Lastly, all participants received up to 10 practice trials of the landing-cutting task. However, even after the practice, participants may have displayed varying landing patterns within their 5 trials.

CONCLUSIONS

Individuals with CAI showed altered movement patterns, including increased ankle-inversion angles and PL activation, during the stance phase of a landing-cutting task when they wore stroboscopic glasses. The results suggest that individuals with CAI may lack the ability to reweight sensory information to adapt their movement to visual disruption. Stroboscopic glasses could offer a cost-effective tool to induce sensory reweighting during dynamic activities.

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