NEUROMUSCULAR CONTROL IN SUBJECTS WITH AND WITHOUT ANKLE INSTABILTY DURING PERFORMANCE OF A DYNAMIC BALANCE TASK

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INTRODUCTION

Not all individuals who suffer a lateral ankle sprain (LAS) will develop ankle instability (AI). This class of individuals can return to a high level of function without symptoms of AI (WAI) and are often termed copers [1]. Recently it has been proposed that subject with AI and WAI have different balance strategies in terms of time-to-boundary during a single leg hop stabilization test [2].

The purpose of this study was to analyze neuromuscular strategies in subjects with AI, WAI, and uninjured control subjects while performing a dynamic balance task (Star Excursion Balance Test [SEBT]). Additionally, the effect of isokinetically induced evertor muscle fatigue on the neuromuscular control strategies was also analyzed.

METHODS

Thirty volunteer individuals (17M/13F, age = 26±7 years, height = 1.71±0.08 m, weight = 68.75±13.09 kg) gave informed consent and completed a physical screening form to assure that they were free from any cardiovascular, neuromuscular, and musculoskeletal conditions or injury (other than LAS for the WAI and AI groups) that may have affected movement patterns.

All subjects completed the Cumberland Ankle Instability Tool (CAIT) to assess the severity of AI. Subjects were then placed in one of three groups: AI, WAI, and control (CTL). Subjects in the AI group had a self-reported history of at least one LAS and a CAIT score equal to or less than 24. Subjects in the WAI group had a self-reported history of at least one LAS and a CAIT score equal to or greater than 28. Subjects in the CLT group were free from any history of LAS and had CAIT scores equal to or greater than 28 (Table 1).

Table 1. Subjects demographic data, mean (SD)

	CLT	WAI	AI
Total Subjects, No.	12	9	9
Age, y	26 (5)	26 (3)	26 (4)
Height, m	1.69 (.07)	1.73 (.09)	1.70 (.11)
Weight, kg	65.99 (11.82)	69.31 (12.74)	76.77 (20.42)
Leg Length, cm	81.32 (3.90)	80.68 (5.78)	81.54 (5.39)
Test Leg Sprain Frequency, No.	n/a	2.11 (1.62)	5.22 (3.15)
Ankle Pain During Sport, No.	1	2	7
CAIT Score	29 (1)	28 (2)	18 (5)

Abbreviations: n/a, not applicable.

Subjects had reflective markers placed on both legs. Kinematic data were acquired at 120Hz using five cameras. EMG electrodes were placed on the belly of the following muscles of the test leg: biceps femoris (BF), peroneus longus (PL), rectus femoris (RF), tibialis anterior (TA), and vastus medialis (VM). EMG data were collected at 1200Hz using an 8 channel EMG system. Additionally, a foot switch was positioned under the first toe of the reaching foot to track toe-off (TO) and toe touchdown (TD) during all the reaching trials.

The SEBT grid [3] was laid over a force plate, which was used to sample kinetic data at 1200Hz. Three reaching directions were evaluated: anteromedial, medial and posteromedial. Subjects performed a baseline measure consisting of three trials per each SEBT direction, and the order of directions was randomized. Immediately following the fatigue protocol (within 2 minutes), all subjects were post-tested in the exact same manner as the baseline test. Only the more affected limb was tested (WAI and AI group), while the test limb was determined by coin flip in the CLT group.

The fatigue protocol was executed on an isokinetic dynamometer. Subjects performed three maximal concentric (CON) and eccentric (ECC) eversion muscle actions at 90º/sec to calculate the maximal ECC eversion force. Then, they performed a fatigue protocol, which consisted of continuous ECC-CON eversion muscle actions at 90º/sec until fatigued. Subjects were considered fatigued when the ECC force output fell below 50% of the maximal ECC force for three consecutive ECC muscle actions.

All data were analyzed using Visual3D software. Kinematic and kinetic data were low pass filtered and reported as difference between angle at TD and angle at TO (kinematic) and value at TD (kinetic). For each muscle, the EMG signal was band-pass filtered, rectified, smoothed, and the signal was normalized to the maximal activation for each muscle during the dynamic trials. The integral of the EMG signal (iEMG) between TO and TD was then calculated and used for further analysis.

A preliminary analysis showed the kinematic and kinetic data were not affected by group placement and fatigue protocol and were excluded from the main analysis. The independent variables were group and time (pre/post fatigue) and the dependent variables were SEBT reaching distance (normalized to leg length) and iEMG of the BF, PL, RF, TA, and VM muscles. Three independent (one per reach direction) 3 x 2

MANOVAs were performed. The Tukey HSD post hoc test was performed when significant group main effect was found. The alpha level was set at 0.05, a-priori.

RESULTS AND DISCUSSION

No significant group x time interactions were found in any of the three directions. Significant time main effects were found for iEMG values from all the muscles analyzed in all three directions (anteromedial reach data presented in Figure 1). Significant group main effects were found in the anteromedial and posteromedial directions. The results of the Tukey post hoc test for the anteromedial direction are presented in Figure 1. The baseline kinematic and kinetic data for the anteromedial reach are reported in Table 2.

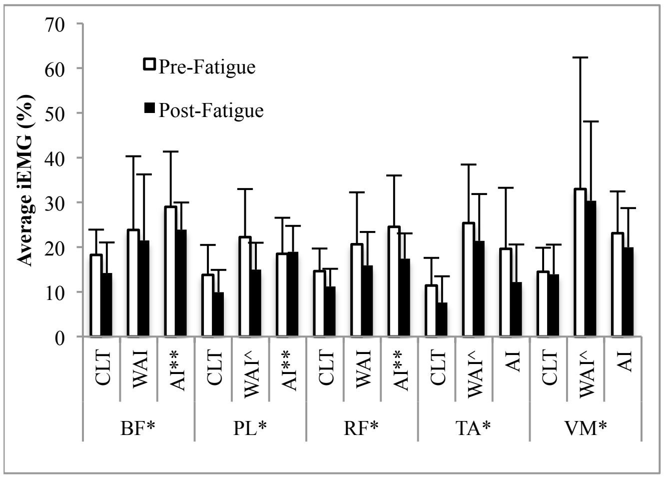

Figure 1. Average iEMG activation in the anteromedial trials.

* Indicates significant time and group main effect ($p < .05$)

^ Indicates significant difference between WAI and CLT groups (Tukey $p < .05$)

** Indicates significant difference between AI and CLT groups (Tukey $p < .05$)

Table 2. SEBT reaching, kinematic and kinetic data, mean (SD)

	Anteromedial		
	CLT	WAI	AI
SEBT, %	84.67 (7.21)	88.56 (6.95)	81.65 (8.61)
ADA, °	28.46 (9.24)	27.18 (6.07)	23.84 (8.20)
AEA, °	9.25 (3.95)	10.29 (3.85)	11.10 (9.53)
KFA, °	42.57 (15.01)	41.34 (12.20)	39.12 (13.46)
AASF, N*BW-1	2.25 (0.70)	2.65 (0.96)	2.66 (0.93)
ALSF, N*BW-1	4.60 (1.20)	4.92 (1.30)	4.53 (1.15)
ACF, $N*BW^{-1}$	6.75 (1.12)	6.99 (1.64)	7.87 (2.32)
ADM, Nm*BW-1	0.75 (0.21)	0.81 (0.25)	0.78 (0.32)
AIM, Nm*BW-1	0.54 (0.18)	0.57 (0.13)	0.61 (0.18)
KFM, Nm*BW-1	1.14 (0.42)	1.30 (0.55)	1.19 (0.35)

Abbreviation: SEBT, Star Excursion Balance Test; ADA, ankle dorsiflexion angle; AEA, ankle eversion angle; KFA, knee flexion angle; AASF, ankle anterior shear force; ALSF, ankle lateral shear force; ACF ankle compression force; ADM, ankle external dorsiflexion moment; AIM, ankle esternal inversion moment; KFM, knee external flexion moment.

The results revealed that all analyzed muscles significantly decreased their level of activation following the isokinetically induced evertor fatigue. These results may be related to the position of the subject on the isokinetic dynamometer. When working in ankle eversion, the rotation axis of the dynamometer is not aligned with the inversion/eversion axis of the foot. Thus, the machine may not completely isolate the eversion movement. As a result, subjects may activate the TA, which is a dorsiflexor/invertor of the ankle, to increase the resistance against which they were working. Additionally, it may also be difficult to externally stabilize the limb positioned at 70° of hip flexion and 45° of knee flexion. Thus, subjects may have activated additional muscles to try to better stabilize the limb throughout the fatigue protocol.

The three groups used different strategies to complete the reaching tasks, however the anteromedial reach best highlights the differences. While the CLT group relied more on passive joint stability, the WAI and AI groups increased muscle activation, which may have helped to overcome mechanical laxity at the ankle and increase the overall stability of the movement.

Following a LAS, the PL muscle has an important function as an ankle stabilizer: both WAI and AI groups presented with higher activation of this muscle compared to the CLT group. In addition to this, the WAI group gave evidence of higher activation of the TA. Co-contracting these muscles may be a more effective strategy to increase the stability at the ankle joint, which may in turn decrease the severity and recurrence of sprains.

The AI group had higher activation of the BF and RF muscles. This may suggest that AI subjects rely more on controlling proximal joints. Co-contracting BF and RF may be a more effective strategy to stabilize and control knee flexion. In addition, in the anteromedial reach while the leg is reaching forward, the pelvis and trunk are moving backwards. As a result, increased activation of the RF may increase the stability of the extension movement that occurs at the hip. While this strategy used by the AI group results in similar reaching performance to the CLT and WAI groups, it may not be as effective in an unstable situation. Failure to control knee and hip joints, along with an already unstable ankle, may represent a threat for reinjury.

It is also interesting that subjects with AI had higher compression force at the ankle when compared with the WAI and CLT groups in all three direction of the SEBT. While compression forces compact the joint and increase stability, they may also increase the functional demand on the joint structure, such as the cartilage. Over time, this may damage the cartilaginous structure at the ankle, generate pain during functional activities, and be a key factor for the development of osteoarthritis noted in AI.

CONCLUSION

A change of neuromuscular control was found following a LAS. Subjects who developed AI relied more on proximal joint control. Subjects who did not develop AI actively stabilized the ankle joint.

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