B5-1 ID123

IS THE HIGH-TOP SHOE MORE PROTECTIVE IN LANDING ON A TILTED SURFACE: A KINEMATIC AND ELECTROMYOGRAPHIC EVALUATION

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The purpose of this study was to explore the effect of high-top and low-top shoes on ankle inversion kinematics and pre-landing EMG activation of ankle evertor muscles during the landing on a combined inverted and plantarflexed surface. Thirteen male subjects were instructed to wear high-top & low-top shoes to execute self-initiated drop landings in each of the 8 landing conditions, i.e. 2 shoes × 4 surface conditions, on an inverted (or combined plantarflexed) platform. Ankle inversion kinematics and the EMG from the tibialis anterior, peroneal longus, and peroneus brevis muscles were collected simultaneously. The results indicated that shoe collar heights did not influence the ankle inversion kinematics during landing. However, wearing high-top shoes resulted in a significant posterior onset time of the tibialis anterior and peroneus brevis muscles, and lowered the pre-landing EMG activation of ankle evertor muscles prior to foot contact during landing on the inverted surface.

KEY WORDS: high-top shoe, ankle inversion, pre-landing EMG, inverted surface.

INTRODUCTION:

Ankle sprains usually occur during excessive plantarflexion and inversion of the foot when people/athletes land on an uneven surface, or perform a lateral cutting maneuver (Wright et al., 2000). Hence several preventive measures have been suggested to change the ankle landing kinematics, like using specially designed high-top shoes or other external support, to decrease the risk of ankle sprains in the past 30 years (Verhagen et al., 2001).
A respectable amount of studies have reported that high-top shoes in comparison to low-top shoes decreased the amount and rate of inversion and decreased the risk of ankle sprains (Ricard et al., 2000). The possible biomechanical reasons have been mainly attributed to limiting ankle inversion ROM (Robinson et al., 1986) and decreasing external joint stress (Barrett & Bilisko, 1995). In contrast, from an epidemiological viewpoint, no direct evidence showed a strong relationship between shoe type and ankle sprains (Barrett et al., 1993). Therefore, there is much discrepancy on the benefit of shoe design on ankle sprain prevention, and the stabilizing effect of high-top shoes in restricting ankle inversion still needs to be examined.
On the other hand, appropriate pre-landing EMG activity is considered to be a protective mechanism that can prevent the ligaments and joints from falling-related injuries (Horita et al., 2002). Since various shoe designs may provide different proprioceptive input, neuromuscular response of the lower leg muscles will be exhibited correspondingly during the fall (Barrett & Bilisko, 1995). Thus, it seems logical to assume that high-top and low-top shoes will have different influences on preparatory muscle activity, which may help us to better understand the potential mechanisms underlying shoe effects in preventing ankle sprains.
Based on the above observations, the purpose of this study was to examine the effect of high-top and low-top shoes on ankle inversion kinematics and pre-landing EMG activation of ankle evertor muscles during landing on a combined inverted and plantarflexed surface .

METHODS:

Subjects: Thirteen healthy male physical education students (age: 21.3 ± 1.2 years, height: 178.6 ± 3.8 cm, weight: 69.9 ± 5.9 kg) participated in this study. None of them had known

musculoskeletal injuries of the lower extremity during the past six months. Each participant had to sign an informed consent approved by the local ethics committee prior to participation.
Testing shoes: High-top (HS) and low-top basketball shoes (LS) customized in a same footwear manufacturer were used in this study. The two types of prototypes had identical outsole and midsole. The design of the high-top upper is comparable with the upper in low-top shoes, except a 6 cm difference in shoe collar height.
Landing protocol: The subjects were instructed to perform 40 trials of self-initiated drop landings from an overhead bar placed 40 cm above the platform. The platform was consisted of a trapdoor platform and a flat platform. All subjects landed with both feet on each of the platform respectively. The customized trapdoor platform was used to initiate 1) a 15° inversion, 2) a 30° inversion, 3) a combined 25° inversion and 10° plantarflexion, and 4) a combined 25° inversion and 20° plantarflexion.
Kinematics: Sagittal kinematic data of the dominant lower extremity were collected at a sampling rate of 120 Hz using eight high-speed infrared cameras (Vicon MX, Oxford Metrics, UK).
Electromyography: A 16-channel Biovision system (Biovision, Wehrheim, Germany) was used simultaneously to record the EMG from the tibialis anterior (TA), peroneal longus (PL), and peroneus brevis (PB) muscles of the dominate leg at a sampling frequency of 1200 Hz.
Data analysis: The main variables discussed in this study for ankle inversion kinematics were 1) the inversion contact angle (θ_{cont}); 2) the maximum inversion angle (θ_{max}); 3) the inversion range of motion (ROM); 4) the maximum inversion angular velocity after foot contact (ω_{max}); 5) the average inversion angular velocity (ω_{ave}). The variables of the EMG included: 1) The onset time of pre-landing EMG activity (the time when muscle contractions were initiated during falling before foot contact); 2) The mean amplitude of the integrated EMG during the 50 ms before touchdown ($aEMG_{pre}$).
Statistics: A 2 × 4 two-way (shoe × surface) repeated measures ANOVA was executed to examine the differences in ankle inversion and EMG responses between the shoe and surface conditions. Tukey post hoc tests were used to determine individual significant differences (16.0, SPSS Inc., Chicago, IL, U.S.A.). The significant level was set at α=0.05.

RESULTS:

Ankle Inversion Kinematics: There was no significant shoe × surface interaction on the ankle inversion kinematics. No significant differences were found in the maximum inversion angle (θ_{max}), the inversion range of motion (ROM), and the maximum inversion angular velocity following foot contact (ω_{max}) between HS and LS for all landing surface conditions (Table 1). However, there was a significant main effect associated with the changes in landing surface conditions for partial ankle inversion kinematical variables (Table 1).

Table 1: Comparison of high-top (HS) and low-top shoe (LS) in ankle inversion kinematic variables (mean ± SD) at different landing surface conditions.

Variables	Shoe condition	Surface condition			
		15°_Inv	30°_Inv	25°_Inv + 10°_PF	25°_Inv + 20°_PF
θ_{cont} (°)	HS	11.8±5.1	13.2±4.6	13.7±5.3	12.4±5.3
	LS	12.4±4.3	12.4±5.3	12.2±4.8	11.7±5.5
θ_{max} (°)	HS	14.8±6.3	28.3±6.7*	23.6±3.4*	23.9±5.4*
	LS	15.2±5.3	29.3±4.7*	25.0±5.1*	25.7±6.5*
ROM (°)	HS	2.4±0.9	15.2±6.1*	12.1±4.4*	13.0±6.1*
	LS	2.7±1.1	17.4±5.7*	13.8±5.5*	14.4±3.7*
ω_{max} (°/s)	HS	62.9±32.5	208.7±112.9*	189.0±109.0*	194.6±106.2*
	LS	61.5±29.3	220.2±125.6*	201.6±115.2*	232.5±127.0*
ω_{ave} (°/s)	HS	49.2±12.5	150.6±60.2*	142.8±52.4*	148.6±64.5*
	LS	46.6±16.3	151.3±76.9*	150.2±69.9*	158.3±77.6*

θ_{cont}, inversion contact angle; θ_{max}, maximum inversion angle; ω_{max}, maximum inversion angular velocity after foot contact ; ω_{ave}, average inversion angular velocity. 15°_Inv, a 15° inversion; 30°_Inv, a 30° inversion; 25°_Inv + 10°_PF, a combined 25° inversion and 10° plantarflexion; 25°_Inv + 20°_PF, a combined 25° inversion and 20° plantarflexion.
* Significantly different from 15°_Inv in the same shoe condition ($p < 0.05$).

Pre-landing EMG Activity: The onset time of TA and PB muscles was significantly later when wearing high-top shoes for 15° inverted surface condition (Figure 1). In addition, the HS group also showed a trend of later onset time of PL ($p < 0.1$). However, for the other three surface conditions, i.e. 30° inversion, combined of 25° inversion + 10° plantar flexion, and combined of 25° inversion + 20° plantarflexion, no significant differences in the onset time of TA, PL, and PB were found between HS and LS during the falling phase.

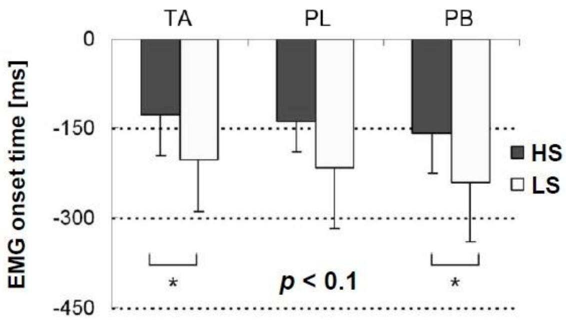

Figure 1: Comparison of the onset time of the tibialis anterior (TA), peroneal longus (PL), and peroneus brevis (PB) muscles between high-top (HS) and low-top shoe (LS) for 15° inverted surface condition. * indicates significant differences with $p < 0.05$.

For the amplitude of pre-landing muscle activity, the $aEMG_{pre}$ of TA in HS was significantly lower compared to LS while landing on the 15° inverted and combined of 25° inversion + 20° plantarflexion surfaces (Figure 2). Similarly, the HS group also showed a 37.2% decrease in $aEMG_{pre}$ of PL and a 31.0% decrease in $aEMG_{pre}$ of PB for the combined of 25° inversion + 20° plantarflexion condition and 15° inversion condition, respectively (Figure 2).

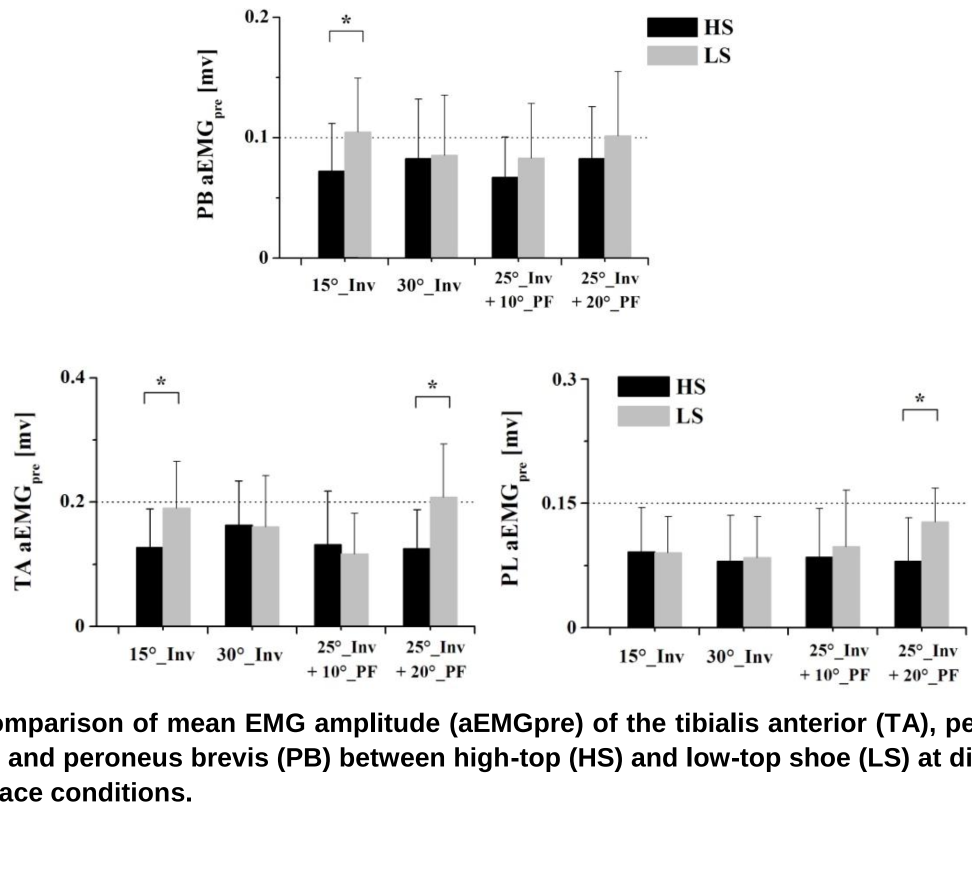

Figure 2: Comparison of mean EMG amplitude (aEMGpre) of the tibialis anterior (TA), peroneal longus (PL), and peroneus brevis (PB) between high-top (HS) and low-top shoe (LS) at different landing surface conditions.

DISCUSSION:

In actual sports activities, ankle inversions mostly occur in a dynamic movement and a more plantarflexed ankle positioning (Wright et al., 2000), such as landing on an irregular surface or on somebody's foot after jumping, instead of in a static and normal foot position condition (Robbins et al., 1995). In the current study, we adopted a more realistic simulation of the lateral ankle inversion sprain – landed on an inverted (and plantarflexed) platform – to evaluate the influence of high-top and low-top shoes on ankle inversion movement. The results indicated that the tilted surface landing should be considered in future investigations of footwear design and lateral ankle performance/injury.

Specifically, the $aEMG_{pre}$ of TA, PL, and PB in HS showed a significant lower amplitude compared to LS. One explanation is that high-top shoes tightened the ankle and changed the proprioceptive feedback, which influenced the onset time and magnitude of pre-landing muscle activation (Papadopoulos et al., 2008). Up to now, it is still unclear of what change in muscle activity represents an obvious beneficial effect after wearing high-top shoes. Furthermore, this effect is likely to be dependent on the specific muscle being assessed, the selected shoes, and the landing condition.

In summary, shoe collar heights did not influence the ankle inversion kinematics during landing on a titled surface. However, high-top shoes adopted in this study resulted in a significant later onset time of the tibialis anterior and peroneus brevis muscles, and lowered pre-landing EMG amplitude of ankle evertor muscles before contacting on the inverted (or combined plantarflexed) surface. These findings provide preliminary evidence suggesting that a smaller muscular effort and changed proprioceptive feedback might be induced when land wearing high-top shoes.

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Acknowledgement

The authors would like to acknowledge supports for the study from the Doctoral Fund of Ministry of Education of China (20103156110002, 20123156120003), and the Cultivating Program of Young Collegiate Teacher of Shanghai Municipal Education Commission (ZZsty12002).