BIOMECHANICAL CHARACTERISTICS OF DROP LANDING ON AN INVERTED SURFACE WITH ANKLE BRACE

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INTRODUCTION

The most commonly used testing protocol to investigate ankle sprain mechanisms and ankle braces is an inversion drop on a trapdoor platform [1, 2]. Only until recently that landing has been incorporated in such applications [3, 4]. Only few studies incorporated landing on an inverted surface [4]. However, no studies have shown biomechanical differences of landing on an inverted surface in comparison to landing on a flat surface. Furthermore, the effects of ankle braces restricting ankle inversion on an inclined surface in landing have not been fully examined. Therefore, the purpose of this study was to examine biomechanical characteristics of drop landing on an inclined surface with an ankle brace.

METHODS

Eleven healthy subjects (6 females and 5 males, age: 24.6 ± 3.5 years, height: 1.70 ± 0.10 m, mass: 65.6 ± 14.9 kg) with no current ankle injury and no history of major lower extremity injuries participated in the study. A seven-camera motion analysis system (240 Hz, Vicon, UK) was used to collect 3D bilateral lower extremity kinematic data. Two force platforms (1200 Hz, AMTI, USA) were used to measure the ground reaction forces (GRF) simultaneously with the 3D kinematics. An inverted surface [45.72 cm (L) × 22.86 cm (W) × 11.43 cm (H)] with a 25° inversion slope was mounted on top of the right force platform with double sided tapes along with a flat surface [40 cm (L) × 40 cm (W) × 4 cm (H)] mounted on the top of the left force platform during drop landing conditions. The subjects performed five drop landing trials from a 0.45 m height on the flat surface without (LF_NB) and with (LF_BR) a semi-rigid ankle brace (Element, DeRoyal Industries, Inc.) and the inverted surface without (LS_NB) and with (LS_BR) brace.

Visual3D (C-Motion, Inc., USA) was used to compute 3D kinematic variables for the right lower extremity. A customized computer program (VB_V3D) was used to determine critical events and values of the computed variables from Visual3D. Surface effects during landing on the flat and slant surfaces were examined using a 2 × 2 (brace × surface) repeated measures ANOVA for selected variables with an alpha level of 0.05 (SPSS 15.0, SPSS Inc., Chicago, IL).

RESULTS AND DISCUSSION

The statistical results showed a significantly higher 1st (F1_Z) and 2nd (F2_Z) peak vertical GRFs in flat surface landing compared to the inverted landing (Table 1). The brace caused higher 1st (F1_X) peak lateral GRFs in the flat surface landing and lower 1st peak lateral GRFs in the inverted surface landing. Furthermore, the slant surface caused a significant decrease in the 1st and 2nd (F2_X) peak lateral GRFs. The maximum inversion angle was significantly increased from the flat surface landing to the inverted surface landing (Table 1). Landing on the flat surface imposed an eversion motion after contact whereas landing on the inverted surface caused inversion movement. The brace did not cause any significant changes in peak inversion or range of motion (ROM) in frontal plane, but a reduced dorsiflexion ROM (ROM_DF).

The greater 1st peak vertical GRF seen in the flat surface landing was initially thought to be associated with a toe-heel landing strategy. A closer examination of ankle sagittal kinematics showed that subjects initially exhibited similar contact angles in both landing conditions. However, significantly less dorsiflexion ROM was observed compared to the flat surface landing indicating a stiffer landing strategy adopted by the subjects during inclined surface landing compared to the flat surface landing. The ankle joint is constrained by the laterally sloped surface resulting in the reduced ROM and therefore the reduced peak GRFs. This stiffer strategy and the eliminated eversion motion commonly associated with landing on a flat surface place the ankle and the rest of the lower extremity in an unfavorable position for impact attenuation.

We expected to see an increase in the horizontal GRF due to the increased surface slope in inverted landing but the results showed reduced peak lateral GRFs. Landing on inverted surface requires greater friction between the shoe and surface to avoid slip (with sand papers on the slope) which may cause greater energy dissipation therefore reduced peak GRFs. Furthermore, the more inverted contact ankle angle places the lateral ankle ligament complex under a tighter and stretched state thus allowing this ligament complex to contribute more to impact attenuation in the inverted landing.

CONCLUSIONS

Landing on an inverted surface causes a reduced peak GRFs but resulted in a stiffer landing with decreased dorsiflexion ROM. The inverted slope places the ankle in a compromised position and may predispose it to inversion sprains. Under the high inversion loading introduced during the landing condition, the ankle brace does not seem to offer significant protection.

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Table 1. Average GRFs and frontal plane ankle kinematic variables: mean ± STD.

Cond	F1_Z (BW)	F2_Z (BW)	FMin1_X (BW)	FMin2_X (BW)	Max_Inv (deg)	ROM (deg)	ROM_DF (deg)
LF_NB	1.28±0.25 [b]	3.20±0.64 [b]	-0.23±0.06 [b]	-0.31±0.08 [b]	5.2±3.9 [b]	-6.7±3.1 [b]	44.4±7.9 [a,b]
LF_BR	1.32±0.25	3.38±0.73	-0.26±0.08	-0.28±0.08	1.8±4.8	-4.0±3.1	35.2±5.1
LS_NB	0.95±0.22	2.86±0.55	-0.09±0.06	-0.21±0.07	25.2±3.9 [1]	13.5±5.1	35.3±5.1
LS_BR	0.85±0.25	2.69±0.56	-0.02±0.07	-0.23±0.11	22.6±5.2	14.4±4.7	28.1±6.2

[a]: significantly different between NB and BR ($p<0.05$) & [b]: significantly different between flat and inverted surfaces ($p<0.05$).