QUANTIFYING STAIR GAIT STABILITY AND FORCE LOADING PATTERNS, WITH MODIFICATIONS TO INSOLE HARDNESS

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SUMMARY

Stair gait falls are prevalent in older adults aged 65 years and older. Extrinsic variables such as changes to the room lighting and insole hardness are two factors that can compromise the balance control system and increase the incidence of falls. Assessments of balance, such as COM-BOS stability margin, and indicators of gait pattern efficiency, such as plantar pressure, force-time integrals and rates of loading and unloading, provide measures concerning the efficiency during stair gait. This research was conducted to investigate stair gait stability and force loading patterns, with modifications to insole hardness. A group of young adults (18-30 years old) descended a 4 step staircase, while kinetic and kinematic measurements were recorded. Results indicated that the hard insoles produced the lowest force loading, low force unloading, and the lowest peak force, while the barefoot condition displayed an inverse relationship. The hard insole displayed a gradual transition from unloading to loading which may suggest more control of balance during stair descent.

INTRODUCTION

Falls are the leading cause of injury in Canada, regardless of age [1]. Recently falls have become the most common cause of injury-related deaths in individuals over the age of 75 years old [2]. Stair-related incidences have accounted for 26% of reported falls in older adults [3]. Since stair gait is performed daily, increased examination is required as falls, greatest occurring in descent (75%), pose a great injury severity [2]. Stability is the ability for an individual to control the body's center of mass (COM) over their base of support (BOS) [4]. Thus stability is influenced by the forces during weight acceptance/tranfer and the rate of foot loading/unloading are important indicators of gait pattern efficiency [5]. Extrinsic risk factors such as footwear, room lighting, or stair design can contribute to increased risk of falls during stair descent [6]. The purpose of this study was to investigate the effects of insole hardness on force loading patterns during stair descent in young adults.

METHODS

Young adults (23.1±2.13 years, 1.71±0.13m, 70.13±13.75kg, n=10 (6 males)) descended a four level staircase with an embedded force plate (AMTI, Watertown, USA) located at the 2nd step, and 4th step (level ground)(Figure1). Participants also wore standardized footwear, pressure insoles (Medi-logic, Schonefeld, Germany) inside the shoes and 12 IRED markers (Optotrak, Northern Digital Inc., Waterloo, CAN) to determining COM motion and BOS location. Each trial was 5 seconds and all data was synced. For safety purposes, the staircase was surrounded with a hand-rail and the participants were instrumented with a 5 point harness. After 5 level walking trials, 4 blocks of trials were performed with a randomly selected insole hardness (soft(S), medium(M), hard(H), barefoot(Bf)) and a randomly assigned lighting conditions (20 or 300 lx). Five repeats were done for each condition of insole hardness and lighting conditions during stair gait.

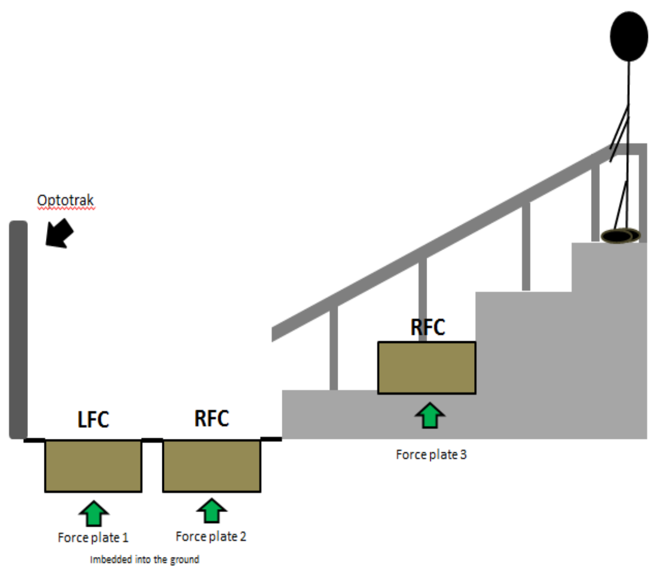

Figure 1: Experimental setup and foot placements during stair descent (RFC: right foot contact, LFC: left foot contact)

RESULTS

Analysis of young adults' insole loading/unloading rates and peak forces measured during contact with the embedded stair force plate (force plate 3) revealed significantly slower force loading rates during hard insole (10.8 kN/s) compared to all other insole conditions (12.103, 12.116, 12.107 kN/s, respectively) ($F_{(3,279)}=7.609, p<0.001$). Also a significantly faster unloading rate during barefoot (7.4 kN/s) was found compared to all other insole conditions (6.29, 6.1, 6.2 kN/s, respectively) during foot contact on force plate 3 ($F_{(2.83,234.6)}$=22.42, $p<0.001$). Lastly the transition from stair to level ground (force plate 2) displayed significantly greater peak forces during barefoot (1.89 N) compared to medium hardness insoles (1.81 N), and even more so when compared to hard insoles (1.79 N) ($F_{(3,270)}$=4.698, $p<0.05$).

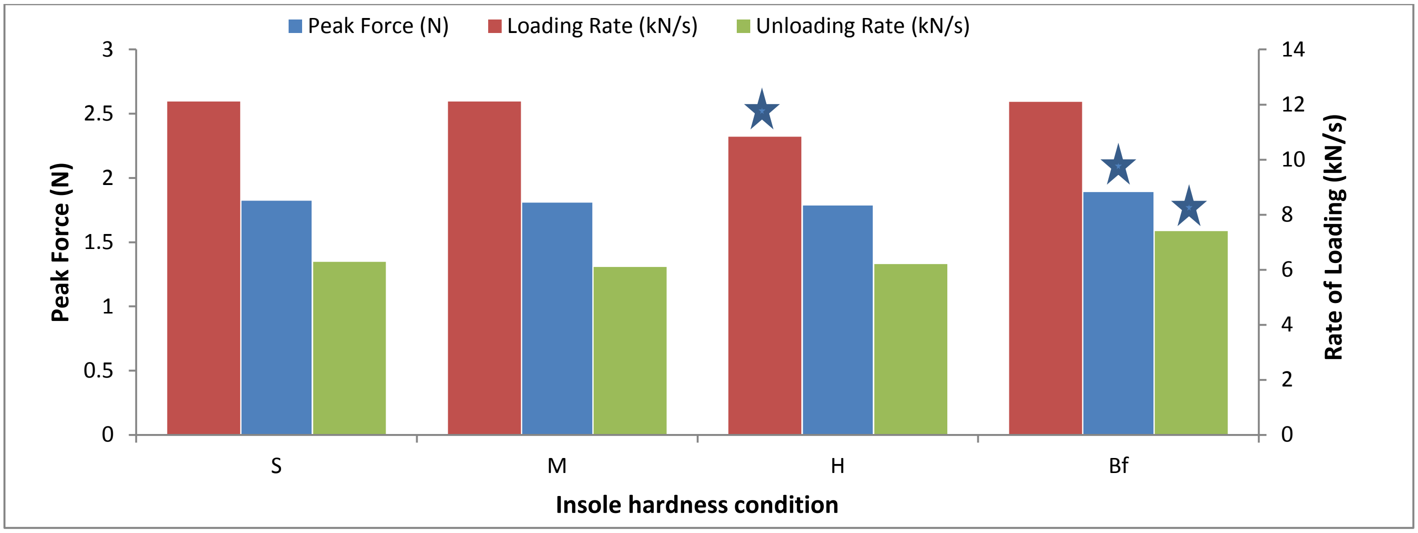

Figure 2: Peak force (N) of force plate 2 and loading and unloading rates (kN/s) of force plate 3 across insole condition for younger adults. (stars indicate significant difference between that condition and all other insole conditions)

DISCUSSION

Results indicate that during barefoot trials there was a rapid loading/unloading of forces causing quick transitions during descent. Conversely, hard insoles displayed the slowest loading/unloading of forces which would permit for a more gradual transition during descent. The quick transitions during the barefoot trials during descent could indicate a compromised stability. In comparison, hard insoles suggest a more gradual transition, which may indicate more control during landing and thus allowing for greater stability during stair descent. Lastly, peak forces during transition from stair to level ground indicate that hard insoles produced significantly less peak force than the barefoot condition. Since stair gait occurs via the forefoot contacting the step first followed by a heel drop, the slower loading and unloading forces while wearing hard insoles may indicate that there is more control of the heel drop in hard insoles during stair gait as compared to the barefoot condition. This control will slow the heel drop and thus result in a decrease in the loading during the foot contact phase of stair contact.

CONCLUSION

Greater stability can be indicated by gradual transitions of force loading and unloadings. Additionally, these rates of force loading and unloading can influence peak force production. When young adults descended the stairs, hard insoles exhibited the slowest loading and unloading forces, which suggest greater stability as opposed to the barefoot condition. Lastly, hard insoles provide greater ability to control the foot as the heel drops after initial forefoot contact. Therefore there is evidence to suggest that insole hardness could influence stability especially during stair gait descent.

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