Effects of Uphill and Downhill Running on Impact and Lower Extremity Loading of Different Habitual Foot Strike Patterns

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Summary

This study aimed to investigate the effects of uphill running (UR) and downhill running (DR) on impact and lower extremity loading of different habitual foot strike pattern runners. Twenty-one habitual non-rearfoot strike pattern (NRFS) runners and twenty-one rearfoot strike pattern (RFS) runners were recruited to run at 12 km/h at random slopes of 10%, 0%, and -10% with their preferred foot strike pattern on the treadmill. The results revealed that habitual RFS runners made some adaptive changes to transition to NRFS, but habitual NRFS runners kept using the NRFS during UR and DR. Habitual NRFS runners experienced less impact loading than RFS runners during level running (LR) and UR, but not during DR.

Introduction

Impact loads during running were recognized as a major risk factor for a series of overuse injuries[1], and foot strike pattern (FSP) was recognized as an important factor affecting impact loading. There are significant biomechanical differences between different habitual FSP during LR, and also between UR, DR and LR[2]. However, it is unclear that how different habitual FSP runners change their foot strike angle (FSA) and thus affect the impact and lower extremity loading during UR and DR. The purpose of this study was to explore how different habitual FSP runners make adaptive changes and which habitual FSP has less impact and lower extremity loading during UR and DR.

Methods

Twenty-one habitual NRFS and RFS runners were recruited respectively. A split-belt instrumented treadmill and motion capture system were used to collect data of GRF and marker trajectories synchronously during running. Participants were required to run at 12 km/h at random slopes of 10%, 0%, and -10% with their preferred FSP on the treadmill. The outcome variables of interest were the FSA, vertical average loading rate (VALR), peak vertical force (FV), joint impulse and cumulative loads (CL). FV and VALR were calculated based on criteria from Davis IS et al.[3]. Per joint CL was calculated by multiplying the time integral of the joint moment curve by the number of strides required to complete a 1000-m distance. Two-way (group × slope) mixed design ANOVA was conducted to quantify the significant effects of groups and slopes on the variables. When significant main effects or interactions were observed, Bonferroni's test was used for *post-hoc* analysis. The significance level was set at 0.05.

Results and Discussion

During UR, 81% and 19% of habitual RFS runners used RFS and NRFS respectively. During DR, 86% and 14% of them used RFS and NRFS respectively. All habitual NRFS runners used NRFS during UR and DR (Figure 1). The results revealed that habitual RFS runners transitioned to adopting NRFS during UR and DR but habitual NRFS runners kept using the NRFS during UR and DR.

A significant group × slope interaction was observed for FV. Both main effects of group and slope were also observed for FV (Figure 1). The results potentially indicated habitual NRFS runners were more responsive to the need for developing greater propulsive forces to generate the required upward acceleration imposed by grade.

A significant group × slope interaction was observed for VALR. Both main effects of group and slope were also observed for VALR (Figure 1). The results potentially indicated that habitual NRFS runners might be better adapted to reducing impact loading during LR and UR, and NRFS might be more suitable for UR.

There was no interaction effect in ankle, knee or hip impulse and CL. For ankle and knee impulse and CL, both main effects of group and slope were observed. But for hip impulse and CL, only the main effects of slope were observed (Table 1).

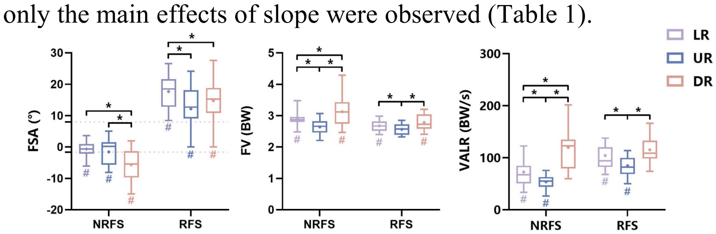

Figure 1: Differences of variables in different FSP and slopes. Note: # indicates significant difference between NRFS and RFS, * indicates significant difference between LR, UR or DR ($p < 0.05$).

Conclusions

During UR and DR at the same speed, habitual NRFS and RFS runners had some different adaptations. Habitual NRFS runners kept using the NRFS during UR and DR. About 19% and 14% of the habitual RFS runners made some adaptive changes to transition to NRFS but 81% and 86% of them adopted the RFS respectively during UR and DR. Habitual NRFS runners experienced less impact loading than RFS runners during LR and UR, but not during DR.

Acknowledgments

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References

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Table 1: The effects of uphill and downhill running on joint cumulative loads of different habitual foot strike patterns (mean ± SD).

Group	NRFS group (n=21)			RFS group (n=21)			*p*-value		
Parameters	LR	UR	DR	LR	UR	DR	Slope	Group	Interaction effect
Hip CL (Nm·s/kg/1km)	90.1±25.9	118.5±36.3	84.2±19.8	81.8±40.3	116.3±27.3	64.9±19.4	**<0.001**	0.156	0.240
Knee CL (Nm·s/kg/1km)	56.7±18.6	54.3±14.4	87.6±22.6	87.6±27.6	73.4±15.1	111.6±20.9	**<0.001**	**<0.001**	0.213
Ankle CL (Nm·s/kg/1km)	169.1±28.6	192.0±33.1	138.5±22.4	140.4±33.7	174.3±18.7	121.9±15.2	**<0.001**	**0.001**	0.347