Kinematic differences between (a)typical initial rearfoot and midfoot contact patterns

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Introduction

One of the most common ways to classify running style is by describing the initial foot contact pattern (IFCP). Based on the first contact with the ground, IFCPs can be categorized as initial rearfoot (IRFC), midfoot (IMFC) or forefoot (IFFC) contact. In shod distance running approximately 75% of runners show an IRFC, 20% an IMFC and 5% an IFFC (Breine *et al.* 2014, Hasegawa *et al.* 2007). The IFCP is related to the initial foot position, but also to the foot unroll kinematics (Pohl *et al.* 2008). In a recent study (Breine *et al.* 2014) we have found that of the registered IRFC contacts, 44% showed atypical center of pressure (COP) patterns. Although these contacts showed an initial COP at the rear 1/3 of the foot (IRFC), they were named atypical IRFC (aIRFC) because the first contact is followed by an initial fast anterior COP displacement at the lateral shoe margin towards the midfoot zone with an early first metatarsal contact after which the COP moves medially into the midfoot zone, similar to IMFC. The fast initial COP movement into the midfoot region in aIRFC seems only feasible with a ‘flatter’ initial foot position. As such, we hypothesize that aIRFC show a ‘flatter’ initial foot position which also resembles to an IMFC. The relevance of discerning the aIRFC can be found in the observed higher instantaneous vertical loading rates of the GRF (VILR) in the aIRFC compared to the other IFCP, which suggests an increased risk for impact related injuries.

Purpose of the study

The purpose of this study was to assess the kinematic differences between aIRFC, Typical IRFC (tIRFC) and IMFC/IFFC runners. We hypothesized that an aIRFC resembles kinematically most to an IMFC.

Methods

Fifty-two recreational and competitive runners (39♂ and 13♀) performed running bouts over a 25m runway at 3.2 m·s⁻¹. Three left foot contact trials were recorded. All subjects wore the same running shoe (Li Ning Magne). GRF and plantar pressures were recorded by a 2m plantar pressure measurement plate (500Hz, Footscan, RSscan) mounted on top of a 2m force plate (1000Hz, AMTI). 3D lower body kinematics were recorded at 200Hz with a 14-camera passive marker motion capture system (Qualisys AB, Gothenburg, Sweden). A 4-segment kinematic model of the left leg (forefoot, rearfoot, shank, thigh) was constructed in Visual 3D (Visual 3D, C-motion, Germantown, MD, USA). For statistical analysis all kinematic and kinetic parameters of the three recorded trials were averaged per subject. Each subject was categorized into the matching IFCP group according to the method described by Breine *et al.* (2014). The IMFC and IFFC were taken together into one IFCP group. ANOVAs with post-hoc analysis (Bonferroni, $p < 0.05$) were conducted to assess between IFCP group differences (tIRFC vs. aIRFC vs. IMFC).

Results

Kinematic variables were divided into ‘global running style’ parameters and ‘distal parameters’. Variables that were found to significantly differ between the IFCP groups are presented in table 1.

Table 1. Kinematic differences between the different IFCP groups.

	tIRFC (n=31)	aIRFC (n=11)	IMFC (n=10)
GLOBAL			
Contact time (s) ^{a,b}	0.254 ±0.016	0.240 ±0.016	0.238 ±0.016
Knee flexion range of motion (°) ^a	29.9 ±4.1	25.5 ±3.4	26.7 ±4.0
Ankle dorsiflexion range of motion (°) ^{a,b,c}	17.3 ±2.8	21.3 ±4.8	25.4 ±4.5
Leg stiffness (kN·m ⁻¹) ^{a,b}	11.1 ±1.9	13.6 ±1.7	13.7 ±1.6
Knee stiffness (Nm·° ⁻¹ ·kg ⁻¹) ^{a,b}	0.096 ±0.017	0.132 ±0.022	0.116 ±0.016
Ankle stiffness (Nm·° ⁻¹ ·kg ⁻¹) ^{a,b}	0.155 ±0.031	0.128 ±0.029	0.121 ±0.032
Leg angle at touchdown (°) ^{a,b}	22.0 ±2.3	19.4 ±1.4	18.3 ±0.9
DISTAL			
Shank posterior inclination at touchdown (°) ^{a,b}	6.0 ±3.1	2.7 ±2.2	3.3 ±2.8
Ankle dorsi(+) or plantar(-) flexion at touchdown (°) ^{a,b,c}	7.2 ±3.5	-3.1 ±4.4	-10.4 ±6.3
Initial ankle plantar flexion range of motion (°) ^{a,b}	6.7 ±1.9	0.9 ±0.9	0.1 ±0.3
Foot-ground angle at touchdown (°) ^{a,b,c}	20.4 ±4.8	7.0 ±5.1	1.6 ±3.1
Rearfoot inversion at touchdown (°) ^{a,b}	9.5 ±3.1	15.0 ±4.0	17.5 ±6.5
Ankle inversion at touchdown (°) ^b	6.4 ±3.6	9.2 ±3.8	10.9 ±5.2
Ankle eversion range of motion (°) ^b	15.8 ±3.5	18.9 ±3.7	20.6 ±4.6

^a significant difference tIRFC vs. aIRFC

^b significant difference tIRFC vs. IMFC

^c significant difference aIRFC vs. IMFC

Discussion and Conclusion

We observed both global running style and distal kinematic differences between the tIRFC and the other two IFCP, indicating that the tIRFC runners have their own distinct running style. **As hypothesized**, only few kinematic differences were found between the aIRFC and the IMFC. Nevertheless, the smaller initial plantar flexion in the ankle, provokes an initial foot placement of 7° that lies between tIRFC and IMFC. Such intermediate foot placement could be classified as an IMFC (Altman *et al.* 2012). But as shown in Breine *et al.* (2014), their VILR is much higher compared to an IMFC. This can be hypothesized to relate to some distal kinematic differences at touchdown and the following impact phase. We observed that almost all aIRFC showed a small initial ankle plantar flexion movement, whereas almost all IMFC showed initial ankle dorsi flexion movement. Further research will investigate to what extent these kinematic differences could explain the previously observed differences in VILR between the different IFCP.

References

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