IDENTIFICATION OF POTENTIAL BIOMECHANICAL RISK FACTORS FOR RUNNING OVERUSE INJURIES FROM A PROSPECTIVE 4HAIE STUDY – PILOT ANALYSES

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The study aimed to identify potential biomechanical risk factors associated with the incidence of running overuse injuries. A total of 747 runners aged 18-65 participated in the study. Runners underwent running biomechanics at a self-selected speed. Subsequently, each runner underwent a one-year follow-up period, during which runners reported running overuse injuries through a weekly online questionnaire. Spatiotemporal distances and biomechanical variables of the right lower limb were analysed. Biomechanical variables were associated with the incidence of running overuse injuries using binary multivariable logistic regression. The incidence of running injuries after one year of observation was 28.9%. Incidence of running overuse injuries was associated, for example, with step width, step frequency, and range of motion of the knee joint from IC to maximum adduction.

KEYWORDS: running-related injury, anatomic regions, kinematic risk factors.

INTRODUCTION: Regular running brings numerous health benefits (Lee et al., 2017). However, running is associated with running overuse injuries that impact running performance and daily activities (Lagas et al., 2020). The incidence of running overuse injuries among runners can reach up to 79% (Lun et al., 2004; Messier et al., 2018). The biomechanical community strives to associate risk factors related to running injuries (Willwacher et al., 2022). Nevertheless, there is still a lack of prospective studies attempting to associate these biomechanical risk factors (Willwacher et al., 2022). The defined potential biomechanical risk factors should be monitored by the research community in intervention studies. It is crucial to investigate whether these variables can be influenced through sports watches and mobile applications, aiming to reduce the risk of running overuse injuries in specific anatomical regions. Therefore, the primary objective of this study was to identify potential biomechanical risk factors for running injuries in individual anatomical regions.

METHODS: This study included 747 recreational runners (304 female and 443 male) from the 4HAIE cohort study. The runners included in the study ran at least 10 km per week and met the WHO-recommended amount of physical activity. Before the baseline measurement, runners had no musculoskeletal injuries or health issues that limited their running for the preceding six weeks. The characteristics of the research sample are detailed in Table 1. The study's design, data collection methods, and informed consent were approved by the Ethics Committee of the University of Ostrava (OU-87674/90-2018).

Table 1. The basic characteristics of the runners.

	Female	Male
Age (years)	36.5 ± 11.4	37.2 ± 11.5
Mass (kg)	64.1 ± 10.2	79.5 ± 9.8
Height (m)	1.68 ± 0.06	1.80 ± 0.06
BMI (kg/m^2)	22.6 ± 3.1	24.4 ± 2.6
Running distance (km/week)	24.3 ± 15.1	27.9 ± 19.6
Running frequency (session/week)	3.1 ± 1.3	3.2 ± 1.5

Note: Data are presented as mean and standard deviation. BMI – Body Mass Index

All runners participated in a comprehensive two-day baseline testing. A detailed description of all the tests they underwent is provided elsewhere (Cipryan et al., 2020; Elavsky et al., 2021; Jandacka et al., 2020). On the second day of baseline measurement, the runners underwent an analysis of the kinematics and kinetics of overground running of the lower extremities. This analysis was conducted using a 10-camera motion capture system (1× Oqus 510+ and 9× Oqus 700+, Qualisys, Inc.) and a force plate (Kistler, Kistler Instruments AG) with sampling frequencies of 240 and 2160 Hz, respectively. The running biomechanics assessment took place at the participants' self-selected speed on a 17-meter-long running track wearing laboratory shoes (Brooks Launch 5, Brooks Sports Inc). The running speed was monitored using two photocells (OPZZ, EGMedical s.r.o.). Markers were placed on the pelvis and lower limbs by Malus et al. (2021). Eight successful trials were utilized for the biomechanical analysis of overground running. A trial was considered successful when the right foot was on the force plate, and the self-selected speed fell within ±5%.
For the kinematic and ground reaction force data, a fourth-order Butterworth low-pass filter with a cut-off frequency of 12 Hz and 50 Hz, respectively, was applied. 3D joint angles of the ankle, knee, and hip were analysed during the stance phase and calculated using the Cardan coordinate sequence x-y-z (Hamill et al., 2014). Ankle, knee, and hip internal net moments were calculated using the Newton-Euler inverse dynamics technique. The foot strike index describing the foot strike pattern was determined according to (Altman & Davis, 2012). In addition, spatiotemporal distances were analysed. All variables were analysed on the right lower limb.
After the baseline measurement, runners underwent a prospective one-year follow-up, which included monitoring running overuse injuries (Elavsky et al., 2021). A running overuse injury was defined as musculoskeletal pain in the lower extremities and lower back requiring medical evaluation or causing a cessation of running or a limitation of distance, speed, duration, or training of running for at least seven days or three consecutive, scheduled running sessions (Yamato et al., 2015). Runners self-initiated or self-reported running overuse injuries through a standardized weekly online questionnaire (Nielsen et al., 2019). In this study, we also analysed the incidence of running overuse injuries in individual anatomical regions.
A binary multivariable logistic regression was used to examine whether biomechanical variables were associated with incidence of running overuse injury. Models were adjusted for gender, age, running distance, and pelvis velocity.

RESULTS: The incidence of running overuse injuries during the 1-year follow-up was 28.9% (n = 216 runners). Incidence by anatomic region is shown in Figure 1.

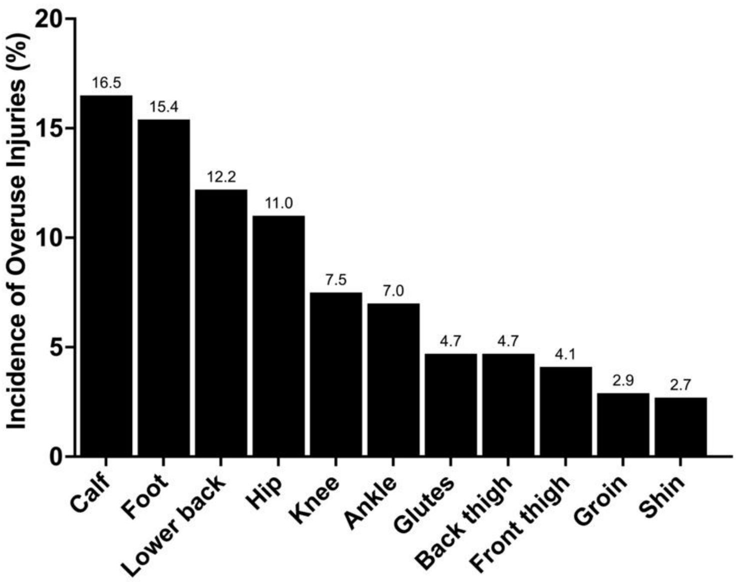

Figure 1: Incidence of running injuries by anatomical region during the 1-year prospective 4HAIE study

The kinematic variables analysed that were associated with the incidence of running injuries are shown in Table 2. Another variable from the logistic regression models that was significantly associated with the incidence of running overuse injuries was age. Higher age was associated with higher incidence for all anatomical regions except the groin. Higher running distance per week was also associated with higher injury incidence in the groin and glutes regions (up to 3% higher risk). Of the kinetic variables tested, none were associated with total or sub-anatomic regions of incidence of running overuse injury.

Table 2. Biomechanical variables associated with running overuse injuries.

Locations	Biomechanical variables	p-value	OR
Foot	Knee angle ROM from IC to maximal adduction *(higher ROM → predictor)*	0.030	1.198
	Step width *(higher step width → predictor)*	0.009	1.102
Ankle	Knee angle ROM from IC to maximal adduction *(higher ROM → predictor)*	0.046	1.305
Shin	Ankle angle at IC – frontal plane *(higher eversion at IC → protective)*	0.009	0.908
	Maximal ankle eversion – frontal plane *(higher maximal eversion → protective)*	0.004	0.892
Calf	No biomechanical parameter		
Knee	Ankle angle at IC – frontal plane *(higher eversion at IC → protective)*	0.034	0.951
Front thigh	Ankle Angle ROM from IC to maximal dorsiflexion *(higher ROM → protective)*	0.043	0.937
	Foot strike index *(higher foot strike index → protective)*	0.035	0.961
Back thigh	Maximal ankle abduction *(higher maximal abduction → predictor)*	0.034	1.092
Groin	No biomechanical parameter		
Hip	Step frequency *(higher step frequency → protective)*	0.028	0.971
Glutes	Hip ankle at IC – frontal plane *(higher adduction at IC → protective)*	0.033	0.887
	Step width *(higher step width → predictor)*	0.020	1.156
Lower back	Knee angle ROM from IC to maximal adduction *(higher ROM → predictor)*	0.044	1.210

Note: Each biomechanical variable was controlled for sex, age, running distance per week, and pelvis velocity in multivariable logistic regression models. OR – Odds ratio, IC – initial contact, ROM – range of motion.

DISCUSSION: The study aimed to identify potential biomechanical risk factors associated with the incidence of running overuse injuries in individual anatomical regions. Our pilot analyses identified potential biomechanical risk factors associated with running overuse injuries. The results of the study suggest that higher knee angle ROM in the frontal plane is a predictor of running overuse injuries in the foot, ankle, and lower back. Furthermore, the results indicate that ankle joint kinematics in the frontal plane are associated with running injury in the shin, knee, front and back thigh (Table 2). A systematic review by (Willwacher et al., 2022) suggests that biomechanical parameters in the frontal plane are more strongly associated with running overuse injuries than those in the sagittal plane. However, these parameters were mostly derived from cross-sectional and retrospective designs. In our prospective study, biomechanical variables from the frontal plane were also more frequently associated with running overuse injuries than those in the sagittal plane.

For a more comprehensive understanding of the aetiology of running injuries, more sophisticated multifactorial statistical analyses will be necessary, such as incorporating intensive physical activity data from one-year follow-up from Fitbit wristbands. Analysis of potential biomechanical risk factors should also be associated with medically diagnosed running injuries. Identified biomechanical risk factors should undergo further examination in multidisciplinary intervention studies aimed at reducing the risk of running overuse injuries, utilizing, for example, mobile apps and sports watches.

A primary limitation of the study was that we did not control for previously diagnosed running injuries in the logistic regression models. Additionally, we did not incorporate compliance into the statistical models for our cohort aged 18-65. Another limitation was that running biomechanics were analysed using standardized laboratory footwear.

CONCLUSION: This study identified several potential biomechanical risk factors associated with the incidence of running injuries in each anatomical region. Knee and ankle joint kinematic variables were most frequently associated with the incidence of running overuse injuries. This information may be useful for subsequent multidisciplinary intervention studies aimed at influencing these biomechanical factors and reducing the risk of running overuse injuries.

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