Treadmill Versus Outdoor Running: Prediction Using A Random Forest Classifier On Biomechanical Measures Of 181,909 Steps

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Context: Wearable sensors can measure gait biomechanics outside of laboratory settings, thus allowing for assessment of the effects of different terrains and intensities on key biomechanical measures. With large enough datasets, machine learning techniques may be used to predict various outcomes. Our purpose was to assess if a random forest classifier could be applied to biomechanical measures captured by wearable sensors to predict whether running steps were performed outdoors or on a treadmill.

Methods: Six young adult distance runners (4 females, 2 males) completed their normal training runs while wearing heel-mounted footpod sensors (RunScribe™, Half Moon Bay, CA) during a 7-day period. Participants completed at least one outdoor and one treadmill run. For each step, the sensors quantified 8 spatiotemoral (velocity, cadence, step length, cycle time, contact time, flight time, contact ratio, flight ratio), 4 kinematic (loading response pronation excursion, maximum pronation velocity, propulsion supination excursion, footstrike type) and 2 kinetic (impact g, braking g) measures. Recorded steps from all completed runs were concatenated into a single dataset. Using the Python module SciKit Learn, a random forest classifier was utilized for prediction of steps performed during outdoor or treadmill runs. All 14 biomechanical measures were entered into the classifier. The algorithm was trained on 70% of the data and then tested on the remaining 30%. This division of data was randomly generated by the machine. Verification of the random forest classifier was reported using mean accuracy, which is the average of how well the classifier performed on the training data, and testing score, which is how well the algorithm performed on the testing data.

Results: A total of 181,909 steps (131,971 outdoor, 49,938 treadmill) were collected from 32 runs (22 outdoors, 10 treadmill). The mean accuracy of the random forest classifier in predicting whether individual steps came from outdoor or treadmill runs was 94.5% in the training data, and the testing score was 91.9%. The Table details the importance rank in the predictive model for each biomechanical measure. Importance rank is a unitless measure generated from the random forest analysis to represent which predictor variables are more closely related with the dependent variable. Means and standard deviations for each biomechanical measure in the outdoor and treadmill runs are also in the Table.

Conclusions: A random forest classifier applied to biomechanical measures collected with wearable sensors was able to predict whether steps occurred while running outdoors or on a treadmill with over 90 percent accuracy. The three highest ranked predictors in the classifier were all frontal plane kinematic measures. Future research should attempt to apply machine learning techniques, such as random forest classifiers, to assess whether biomechanical measures can distinguish between steps taken by injured and uninjured distance runners.

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Table: Importance rank and descriptive statistics for biomechanical measures.

Feature	**Importance Rank**	**Outdoor Steps** (n=131,971) *Mean (SD)*	**Treadmill Steps** (n=49,938) *Mean (SD)*
Maximum Pronation Velocity (°/s)	0.144	668.4 (436.2)	393.2 (262.6)
Pronation Excursion During Loading Response (°)	0.122	11.4 (11.4)	10.8 (7.9)
Supination Excursion During Propulsion (°)	0.117	8.5 (12.6)	8.0 (10.3)
Step Length (m)	0.116	1.3 (0.2)	1.4 (0.3)
Footstrike Type*	0.083	5.6 (3.1)	4.7 (2.6)
Velocity (m/s)	0.071	3.7 (0.7)	3.8 (0.9)
Cycle Time (ms)	0.063	702.5 (72.3)	738.0 (71.6)
Cadence (steps/min)	0.058	172.2 (13.4)	163.8 (12.9)
Braking g	0.044	10.8 (3.1)	9.3 (3.0)
Contact Time (ms)	0.040	277.5 (79.5)	303.8 (92.2)
Contact Ratio	0.040	66.9 (31.3)	72.4 (35.7)
Flight Ratio	0.038	22.9 (9.2)	20.7 (10.3)
Flight Time (ms)	0.037	73.5 (50.5)	65.0 (61.0)
Impact g	0.027	11.1 (3.4)	10.0 (3.4)

* Footstrike type is a unitless metric in the RunScribe™ algorithm that is on a scale from 0 to 15 with lower values representing rearfoot strike, middle values representing midfoot strike, and higher values representing forefoot strike.