The Search for The Holy Grail in Running Biomechanics: Uncovering Unique Biomechanical Running Profiles with Artificial Intelligence

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INTRODUCTION: Running styles adopted by runners can have an impact on exposition to risk of injury. This study aimed to identify whether different biomechanical running profiles among healthy asymptomatic runners, and to examine their lower limb mechanical loading characteristics, while evaluating potential implications for injury risk.

METHODS: The study was approved by an Institutional Review Board (Study ID: 87148418.7.0000.5257). All subjects signed an informed consent. Seventy-nine healthy runners ran on a treadmill at 2.92 m/s. Step cadence, stance time, vertical oscillation (range of vertical displacement of the center of mass during a cycle), duty factor (ratio of stance time over stride time), vertical stiffness (ratio of the change in vertical ground reaction force to the change in vertical oscillation), ground reaction force, and anteroposterior, lateral, and vertical smoothness (calculated using the spectral arc length function[1]) were determined from three-dimensional kinematic data collected using an eight-high-speed camera motion analysis system. A combination of Principal Component Analysis, Self-Organizing Maps, and K-means clustering techniques was used to delineate distinct biomechanical running profiles. Kruskal-Wallis tests were conducted to compare the numeric variables among groups. Pearson's Chi-squared tests were employed to compare observed frequencies of categorical variables among groups. The level of significance was set at 0.05.

RESULTS SECTION: Five distinct biomechanical profiles were identified ($p<0.001$, Fig.1). Profile 3 showed characteristics associated with the lowest joint overload due to reduced peak ground reaction forces and greater movement smoothness. Profile 5 exhibited the highest joint overload, driven by high ground reaction forces, low duty factor, and high vertical oscillation. Profile 1, despite having a low step cadence, exhibited low joint load due to a high duty factor and low peak ground reaction forces. Profiles 2 and 4 showed contrasting running patterns but maintained moderate smoothness and peak ground reaction forces.

DISCUSSION: The study reveals five distinct biomechanical running profiles among healthy subjects, each presenting varying lower limb mechanical load profiles, potentially contributing to different injury risks. A novel finding is the interaction between certain biomechanical variables, some inducing higher mechanical loads while others reducing them.

SIGNIFICANCE/CLINICAL RELEVANCE: The findings underscore the complexity of running biomechanics and shed light on the limitations of models focusing on isolated biomechanical factors. The identification of these distinct running profiles can inform future research examining injury risk within each profile and guide the development of tailored training regimens to balance capacity and demand, potentially contributing to injury prevention in runners.

REFERENCES:
1. Balasubramanian et al. On the analysis of movement smoothness. J Neuroeng Rehabil. 2015 Dec 9;12:112. doi: 10.1186/s12984-015-0090-9.

IMAGES AND TABLES:

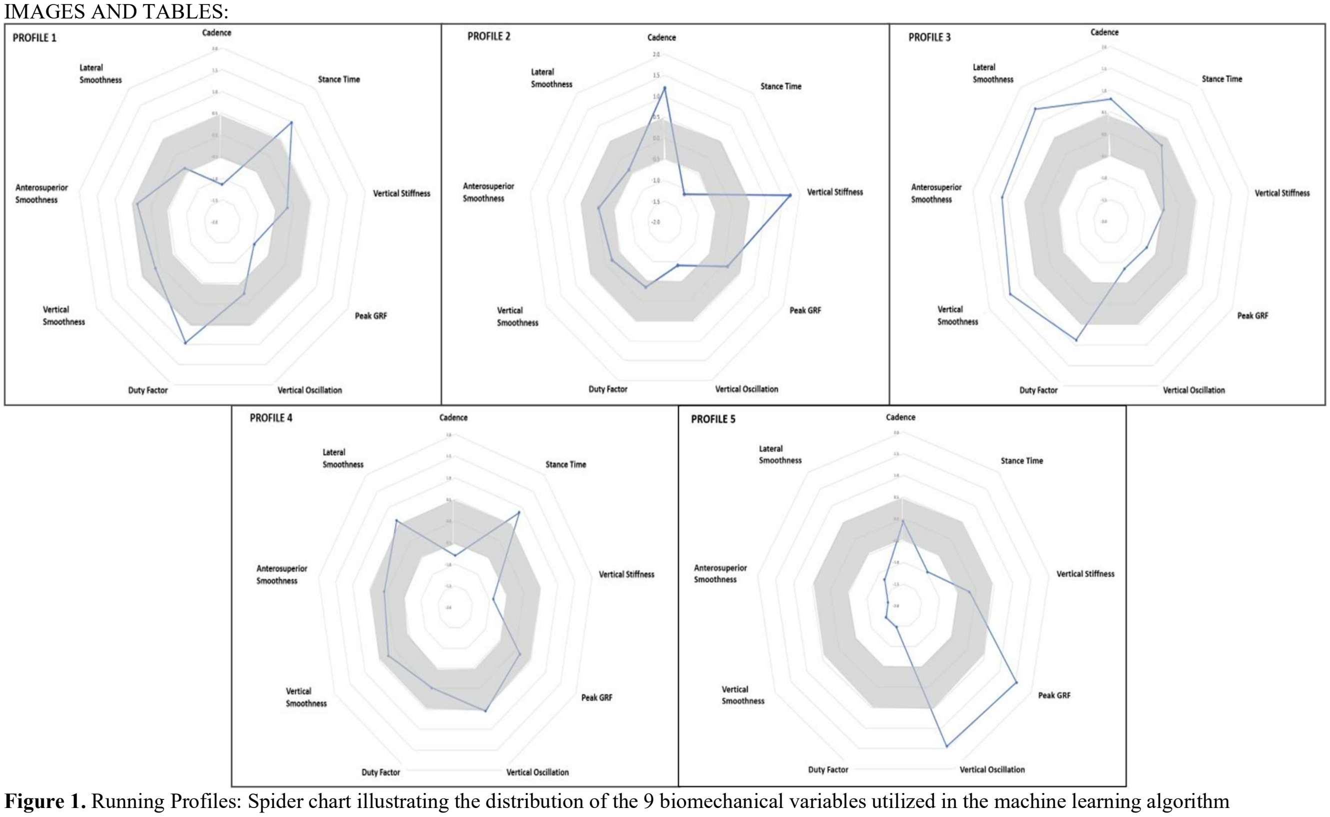

Figure 1. Running Profiles: Spider chart illustrating the distribution of the 9 biomechanical variables utilized in the machine learning algorithm (standardized by z-score). Values situated below and above the shaded area are the most significant for the profile. P1 (n=12); P2 (n=22); P3 (n=16); P4 (n=15); P5 (n=14).