

IMPACT OF DIFFERENT TYPES OF TERRAINS AND CARRYING OF THE LOADS ON CHANGES IN WALKING AND MOVEMENT PATTERNS

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INTRODUCTION

Forestry is among the most physically demanding and hazardous professions, with slips, trips, and falls accounting for a substantial proportion of work-related injuries. Irregular terrain typical of forest environments imposes high demands on locomotor control and body balance. Most gait research has been conducted on laboratory surfaces [1, 2]. This study aimed to quantify how human gait adapts across three typical terrains relevant to forestry work—solid surface, forest trail, and natural forest environment, and how the structure of movement changes in relation to the carried load that workers have to carry while performing their work activities. We hypothesized that (i) spatiotemporal gait variability and changes in foot-strike patterns would increase with terrain complexity [3, 4], and (ii) these adaptations would indicate higher fall risk and reduced dynamic stability [5] in forest environments compared to solid ground.

METHODOLOGY

This study examined walking and movement patterns across different terrains with and without a 10-kg load simulating a chainsaw. 23 subjects completed unloaded trials; 15 subjects completed loaded trials (total 14 men, 9 women; mean age 34). Participants walked at a self-selected comfortable speed over three controlled outdoor surfaces: (1) solid, even ground; (2) an unpaved forest trail; and (3) a natural forest floor with roots, stones, and irregular soft soil. Using 17th wearable IMU's (consisting of accelerometers, gyroscopes, and magnetometers, and specific SW apps), we digitally recorded and quantified walking patterns and body posture, and other risk levels related to their movements.

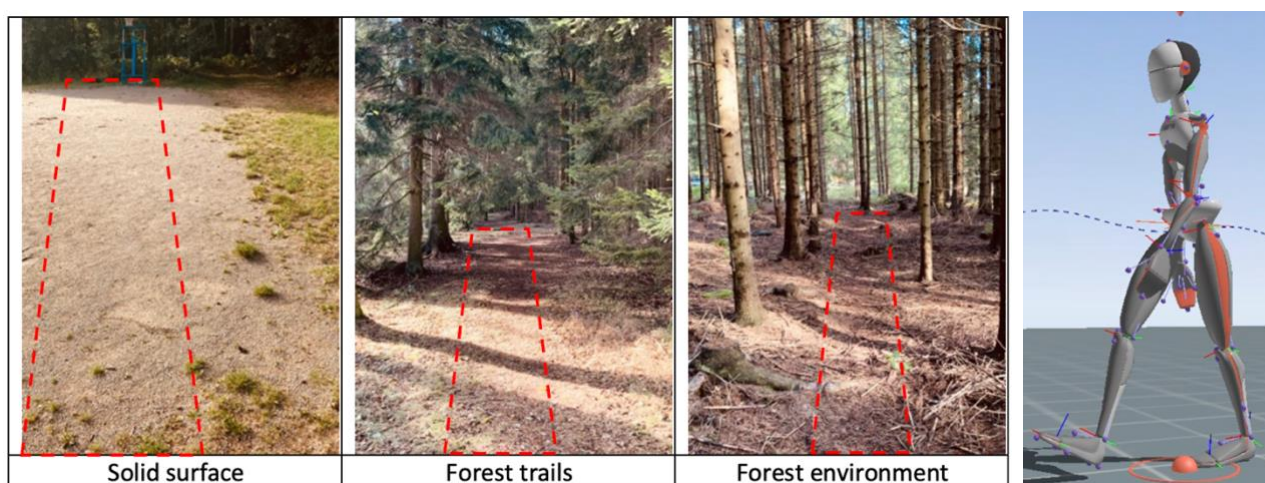


Fig. 1: Three types of outdoor surfaces: solid surfaces, forest trails, and forest environments.

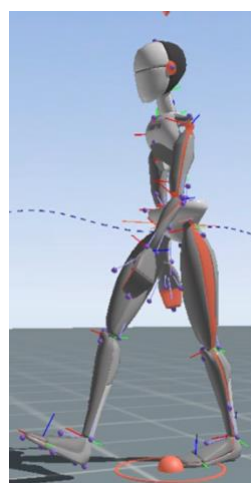


Fig. 2: Gait recording

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RESULTS

Project results showed that the type of surface strongly shaped the gait pattern. On solid ground, participants walked stably and efficiently: ~19 steps (for the test distance), cadence 102.5 steps·min⁻¹, tiny variability in width (±0.6 cm) and length (±1.9 cm), near-max heel-strike time (99.7%), and high overall stability—suggesting low neuromuscular demand and accident risk. On forest terrain, the gait pattern adapted to the surface: more steps (~27.5), slightly lower cadence (99.6 steps·min⁻¹), larger variability (width ±2.7 cm; length ±8 cm), and a reduced heel-strike share (80.1%) offset by greater toe engagement (19.9%). These shifts indicate a more cautious strategy with reduced stability and higher functional demands.

Parameter	Minimum	Maximum	Mean	Standard dev.
Speed (m/s)	0.87	1.61	1.19	0.15
Cadence (steps/min)	90.64	121.95	102.86	8.10
Steps (No)	13.00	35.00	24.84	4.53
Step length Difference (Value (cm))	9.32	16.27	4.28	4.76
Step width Difference (Value (cm))	1.47	3.27	0.19	0.72
Foot Strike Total Heel (%)	58.00	100.00	89.25	11.50
Foot Strike Total Toe (%)	-	42.00	10.75	11.50

Tab. 1: Basic statistics of the major gait parameters.

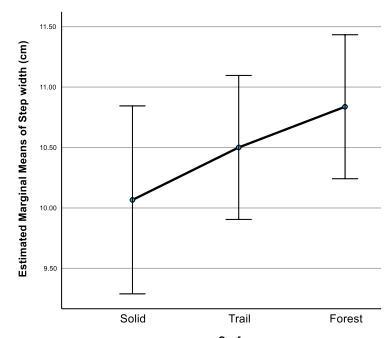


Fig. 3: Influence of surface on step width.

The addition of simulated load had a impact on gait structure and the level of body instability during movement in forestry terrain - there was a decrease in step increment and a decrease in cadence (26.4 steps; 98.7 steps min⁻¹), variability in width (+/- 2.9cm), and step length increased (+/- 8cm). The proportion of heel strike time during the stride decreased slightly (79.2%), and the percentage of toe engagement time increased (21.8%). The change in movement regularity with increasing load became much more irregular and scattered, indicating higher demands on postural control of the body and reduced body stability.

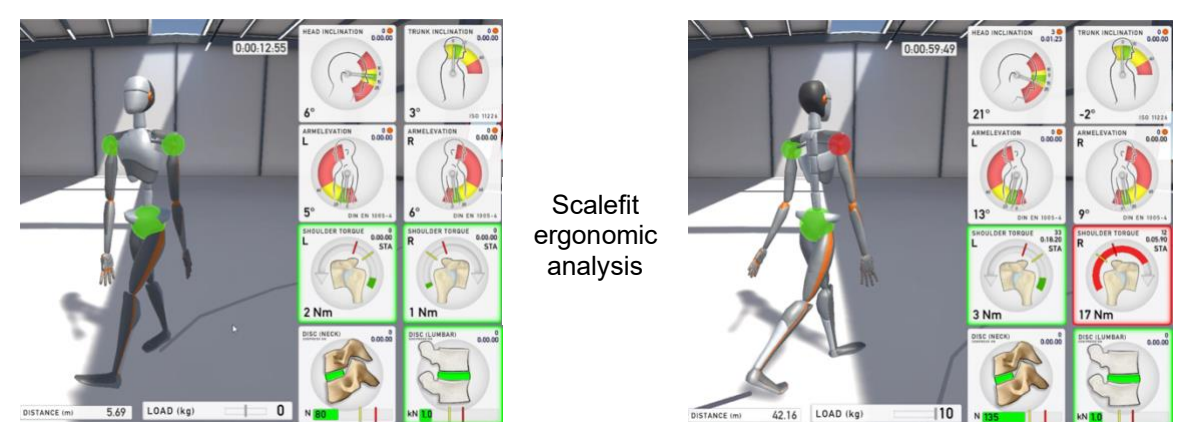


Fig. 4: Influence of simulated loads on Ergonomic risks and workload - left without/ right with 10 kg load.

These findings are important not only for safety and health prevention, but they also may contribute to other areas as the prevention of injuries of older workers, the design and development of assistive systems, augmented reality information systems, and the Human Robotics applications.