Novel Application of Radar Technology in Human Movement Science and Physical Activities

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INTRODUCTION

- Traditional motion capture records movements in a 3-D Cartesian coordinate space and can be grouped into three main categories: surveillance, control, and analysis [1].
- The gold standard is an optical motion capture system capable of collecting kinematic data, such as position, duration, velocity, and acceleration [2].
- Other technologies have been explored to replicate or replace optical motion capture systems but most have inherent flaws [3].
- RADAR (Radio Detection and Ranging) is a technology that shows promise as a standalone system that might replicate aspects of an optical motion capture system [4,5,6,7,8,9,10,11].

PURPOSE

- The purpose of this study is to examine a custom Continuous Wave (CW) radar system to validate and help determine the relationship of biomechanical motions to the resultant features in the radar spectrogram by analyzing daily activity motions (stair walking, sit-to-stand movement, squats, lunges, and cycling) in healthy adults.

METHODOLOGY

- Data has been collected on eight participants (6 females; age: 23.88±2.47 years; mass: 72.76±12.96 kg; height: 1.69±0.09 m).
- Participants were excluded if they had current lower extremity injuries or pain within the last year, neurological or physiological problems that would affect the required activities.
- Data for each participant was collected in a single 1-hour visit to the Ball State University Biomechanics laboratory.
- The activities were captured using a 12-camera motion capture system (VICON Inc., Denver, CO, USA) at 100 Hz and three force platforms (AMTI, Inc., Watertown, MA, USA) at 2000 Hz with a modified Plug-In Gait marker set, and a custom built CW radar system at 2.54 Hz.
- Stair walking was performed on a custom built set of five stair steps; cycling was performed on a stationary cycle ergometer (Monark, Vansbro, Sweden); squats, lunges, and sit-to stand activities were performed as body-weight movements; sit-to-stand movements were performed with a box to sit upon.

RESULTS

Although data has been collected for eight participants, the process of extracting quantitative data (phase duration, cycle duration, cycle frequency, step length) from the radar returns has yet to be performed. The technology and application are novel and the methods to obtain quantitative data require more time to develop. The spectrograms of the radar returns and the models from the motion capture system for pilot data can be found below.

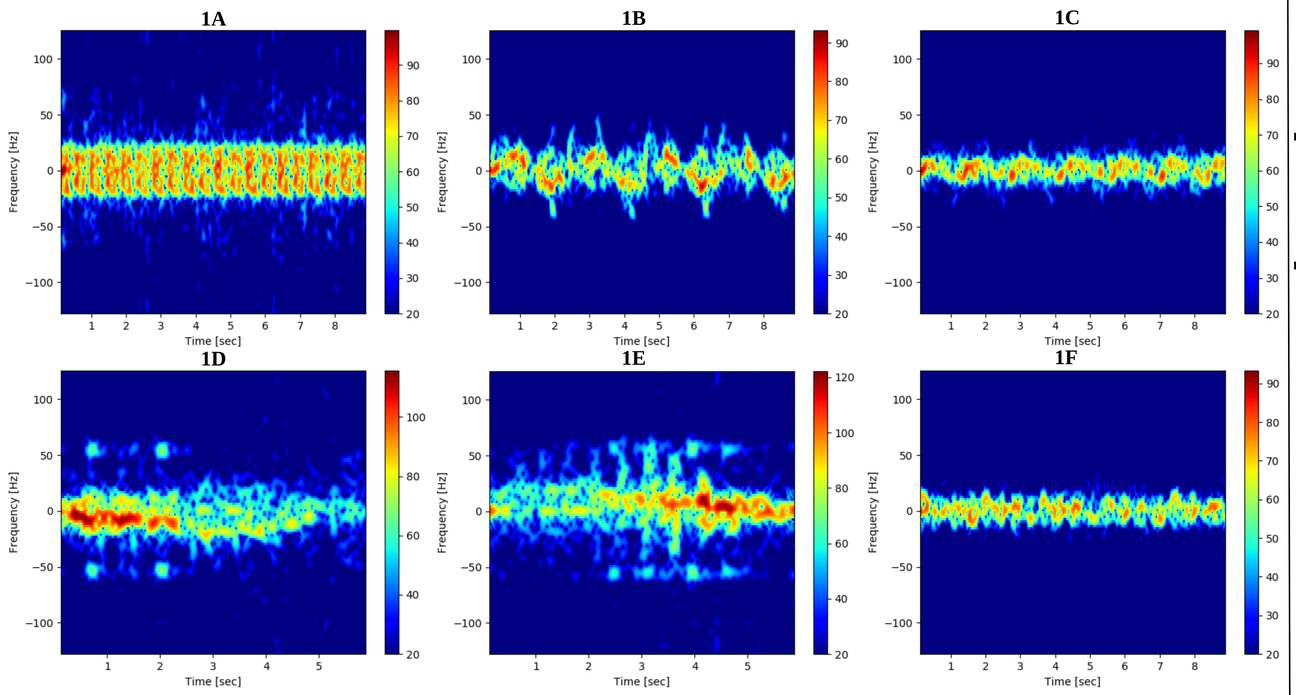

Figure 1: Spectrograms for cycling (A), lunge (B), squat (C), walking down stairs (D), walking up stairs (E), and sit-to-stand movement (F)

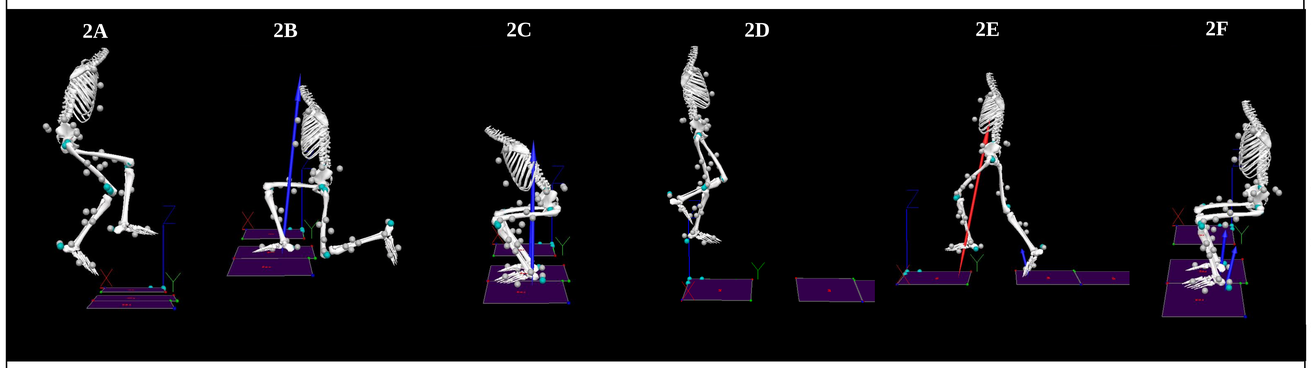

Figure 2: Motion capture modeling for cycling (A), lunge (B), squat (C), walking down stairs (D), walking up stairs (E), and sit-to-stand movement (F)

- The color of the spectrograms indicates the power of the radar return signal; stronger returns are red, weaker returns are blue. The central band in most of the spectrograms (1B, 1C, 1D, 1E, and 1F) demonstrates the strongest return, which comes from the torso. In 1A, the torso does not move much during cycling, thus most of the return is from the leg movement.
- The amplitude of the return wave directly corresponds to velocity. The peaks above and below the central band are micro-Doppler returns, and are returns from the upper and lower extremities. In most of these movements, the extremities move at a higher velocity than the torso, which results in the observed peaks (higher positive and negative velocity about the torso band velocity).

DISCUSSION

- Visual analysis of the spectrograms confirm that different movements exhibit distinct radar returns [12,10,13,14,15].
- While the technology and data extraction techniques are still being developed, these preliminary findings suggest that radar can be used for not only human detection, but also for detailed human movement analysis.
- It has been hypothesized that not only can the desired variables be quantified from the radar returns, but that the variables will valid compared to the optical motion capture data [9,11].
- Future research includes varying radar placement and distance with respect to the target, type of radar and antennae, and other types of movements and populations in order to expand the application of radar in the fields of movement and exercise science.

Conclusion

Radar has the potential to extract important biomechanical parameters and to be implemented in hospitals, clinics, and the home for patients, athletes, and the general population to improve patient rehabilitation, injury prevention, and analysis of daily and sports-related movements.

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