Term Paper Review - ME6230: Mechanics of Human Movement

Title: “Ground Reaction Forces and Lower Extremity Kinematics When Running With Suppressed Arm Swing”

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This is a comprehensive review of the paper “Ground Reaction Forces and Lower Extremity Kinematics When Running With Suppressed Arm Swing”.authored by namely, Ross H. Miller, Graham E. Cadwell, Richard E. A. Van Emmerik, Brian R. Umberger and Joseph Hamill from the Department of Kinesiology, University of Massachusetts. The paper was published in December of 2009 in the Journal of Biomechanical Engineering, a journal which [1] “*reports research results involving the application of mechanical engineering principles to the improvement of human health. The scope of the journal ranges relevant topics from basic biology to biomedical applications and includes theoretical, computational, experimental, and clinical studies*”. The paper dwells into constructing a practical study to estimate the effect of arm swing suppression when running on Ground Reaction Force (called GRF), Kinematic Variation of Lower Limb Joint Angles and to analyse the observations and discuss the incorporation of the effect of arm swing suppressed running in musculoskeletal models used in computer simulations of the discussed parameters. Previous research work in the same domain was largely limited to specific subsets of the study done in the paper and their main common conclusion is that [2]*“arms are important in supporting the center of mass and maintaining an anterior direction of progression”*. This paper solves the need for a more comprehensive practical analysis of the same problem with more tangible conclusions.

The experiment designed by the authors has done due diligence to test with a statistically sound set of subjects in order to achieve accurate experimental readings. The sensor instrumentation on the subjects in the experiment, motion capture system and the strain gauge force platform was satiate to cater to the different requirements of the experiment. Two different arm swing suppressed running cases, one with arms across the chest (case RC) and another with the arms behind the back (case RB) were studied along with a normal arm swing running case (case N). This was done by the authors to compare the relative effect of arm swing suppression to the relocation of the center of mass of the arms. The data analysis of the experimental data is of a sophisticated level employing methods like ANOVA and false discovery rate adjustment. The joint angles have been calculated using appropriate rotational-transformation and the different readings have been appropriately averaged and scaled for comparison. The effective size (called ES) parameter has been defined to qualify the significance of deviations. The authors have defined the suppressed arm swing cases to exhibit similar nature if they lie between the two standard deviation range around the mean normal arm swing case readings.

The authors observed that with respect to GRF, the second vertical peaks of both RC and RB decreased in magnitudes in that order but the only significant change of good ES was of the lateral GRF peaks with respect to the N-case. Several of the joint angle readings fell out of the two standard deviation band and the following parameters varied with significant ES: [2]*"peak hip adduction, knee flexion, and knee adduction for condition RC, and peak hip internal rotation, knee flexion, and knee adduction for condition RB"*. The timing across various observations for different subjects was highly correlated leading to minimal effect on GRF peak timings due to arm suppression with the exception of a slight stance-phase duration increase. This indicates that the authors have employed strict similarity vetting across subjects and have weeded out any chances of outliers biasing the conclusions. Between the two different arm swing suppressed methods there was no significant difference except for the lateral GRF peak, leading to conclude that there exists only low dependency on the variation of the center of mass and the major factor was, in fact, the arm suppression alone. One of the visually counter-intuitive observations made by the authors was in the sagittal plane joint angle variation in arm swing suppressed cases. They seemed to differ by a very low magnitude while visual observation suggested otherwise and this could be borne out of the difficulty to measures values using skin mounted markers.

The fact that the centre of mass support changes in the arm suppressed cases are clearly conclusive and the longer stance phases could be due to the increase in the effect of decreased GRF on the impact impulse. This has a strong relation to the Hinrichs citation which quantifies how much of the vertical impulse the arm swing accounts for, a clear example of how relevant citations have been used to draw more meaningful conclusions. The utility of the effective size method can be seen in the comparison between the free moments of the different cases where even though there were variations, the statistical significance of those observations was poor due to bad

ES. This contradicts the paper's initial hypothesis and all previous studies which state high correlation between arm swing and free moments and this is the most significant result from the study. One of the cases that support this low variation of the free moment could be that trunk bending is more significant in counterbalancing transverse free moments than arm swing in running as opposed to arm swing being more significant than trunk bending during walking. The latter is supported by evidence from previously concluded studies cited in the paper. This opens up a new interesting research problem to study the effect of trunk bending in countering transverse free moments while running. The incorporation of arm swing related effects in computerised musculoskeletal models is vastly minimal and this study is crucial as it gives evidence that various parameters cross the two standard deviation band. Users should strongly consider whether this variation is acceptable to their application before choosing to neglect the arm swing effect in their models. On of the options available is to estimate the forces at the shoulder joint and apply them as external forces in the model. All of this poses a significant computational load but it wouldn't be long before sufficient computational advancements would be made to support these studies.

On the whole, this is a well-structured paper which introduces the problem in a very clear manner and approaches the study systematically. It has been well-formatted with simple language usage not leading to any unwanted misinterpretations and the grammar is very clean. The tables and graphs were very vital in the paper the graphs could have had a better impact if the mean line was plotted along with the two standard deviations shaded region of the readings from the normal arm swing case. IMU's and other sensors could have been used to supplement motion capture data. The notations used in the paper are very consistent. Thus it is a very well written paper which arrived at meaningful conclusions and has established a good scope for future research in the same domain.

Citations:

[1] https://asmedigitalcollection.asme.org/biomechanical/pages/about

[2] Ross, H. M., Graham, E. C., Richard, E. A., Brian, R, U., and Joseph, H., 2009, "Ground Reaction Forces and Lower Extremity Kinematics When Running With Suppressed Arm Swing", Journal of Biomechanical Engineering, Vol. 131.