SIMPLIFIED PLANAR KINEMATIC CHAIN MODEL OF INITIAL START PHASES IN LUGING

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Introduction

In the sport of luge the start plays an important role for an overall performance (Bruggemann et al., 1997). During the initial phases of the start, when an athlete is holding the start handles, athlete's body and the sled are forming a closed kinematic chain – athlete's hands are closing the chain through the handles, while athlete's legs and feet are closing the chain through the sled and the ice surface. The aim of the present study was to develop a planar kinematic chain model for two initial start phases in luging, and to evaluate limitations of this model.

Materials & Methods

The closed kinematic chain was modelled using Simulink SimMechanics™ computer modelling environment. Kinematic drivers for the model were obtained from motion capture data (Yeadon and King, 2008). Motion capture data were also used as reference data to evaluate the models. Motion capture was performed with 3 high-speed cameras at 100 fps using Simi Motion software. Anthropometric measurements of one athlete after receiving an informed consent were used to imitate segment lengths in the model. Segment inertia parameters were estimated as in (de Leva, 1996; Zatsiorsky et al., 1990).

All created models represent one side of the athlete's body. The models were created in XZ plane, assuming X axis is pointing in the direction of horizontal movement of the sled, Z is vertical axis. Kinematic chains of the models are shown at Figure 1.

4-segment model consists of torso (from point Cox to Acr), sled (SL), upper arm (points Acr to Cub) and forearm (points Cub to Man) segments. SL segment has one DOF – horizontal transition. In all points segments are allowed to rotate around Y axis. In 5-segment model the torso is divided into two segments – upper torso (points Acr to Th9) and lower torso (Th9 to Cox). 6-segment model is the same as the previous, but with a hand segment added (points Man to Met). 7-segment model consists of upper torso, lower torso, sled, upper arm, forearm, thigh (points Cox to Con) and shank (points Con to Mal) segments.

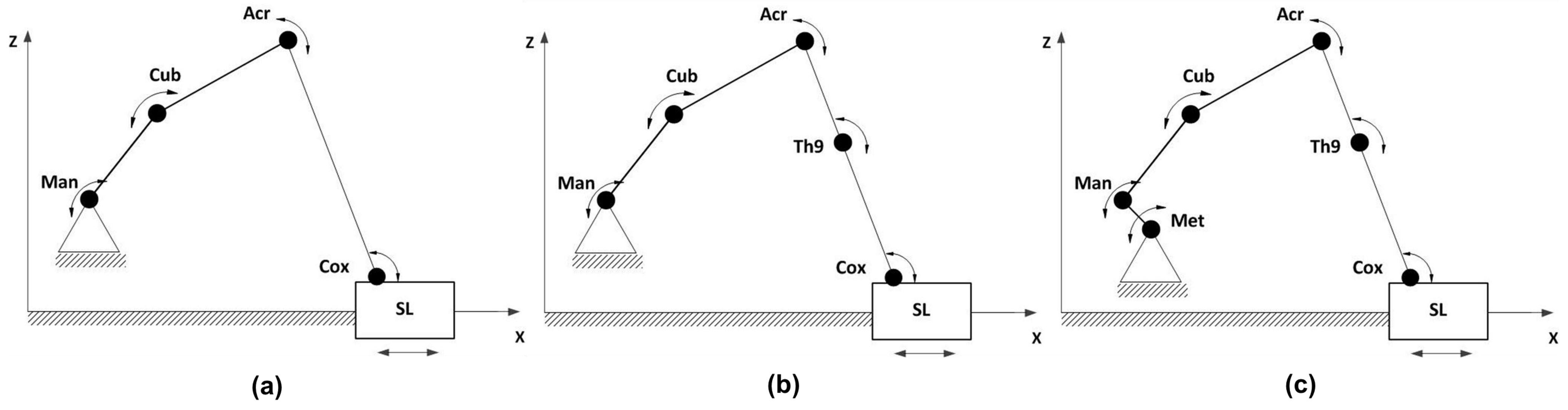

Figure 1. Kinematic chains of 4- (a), 5- (b) and 6-segment (c) models.

Results & Discussion

4-, 5-, 6- (without leg segments) and 7-segment (with leg segments) models were developed. Testing of the models had shown that modelling the torso with one segment (4-segments model) is inappropriate for the selected movements. A model with two-segment torso gave a more realistic representation of the athlete's performance (Figure 2).

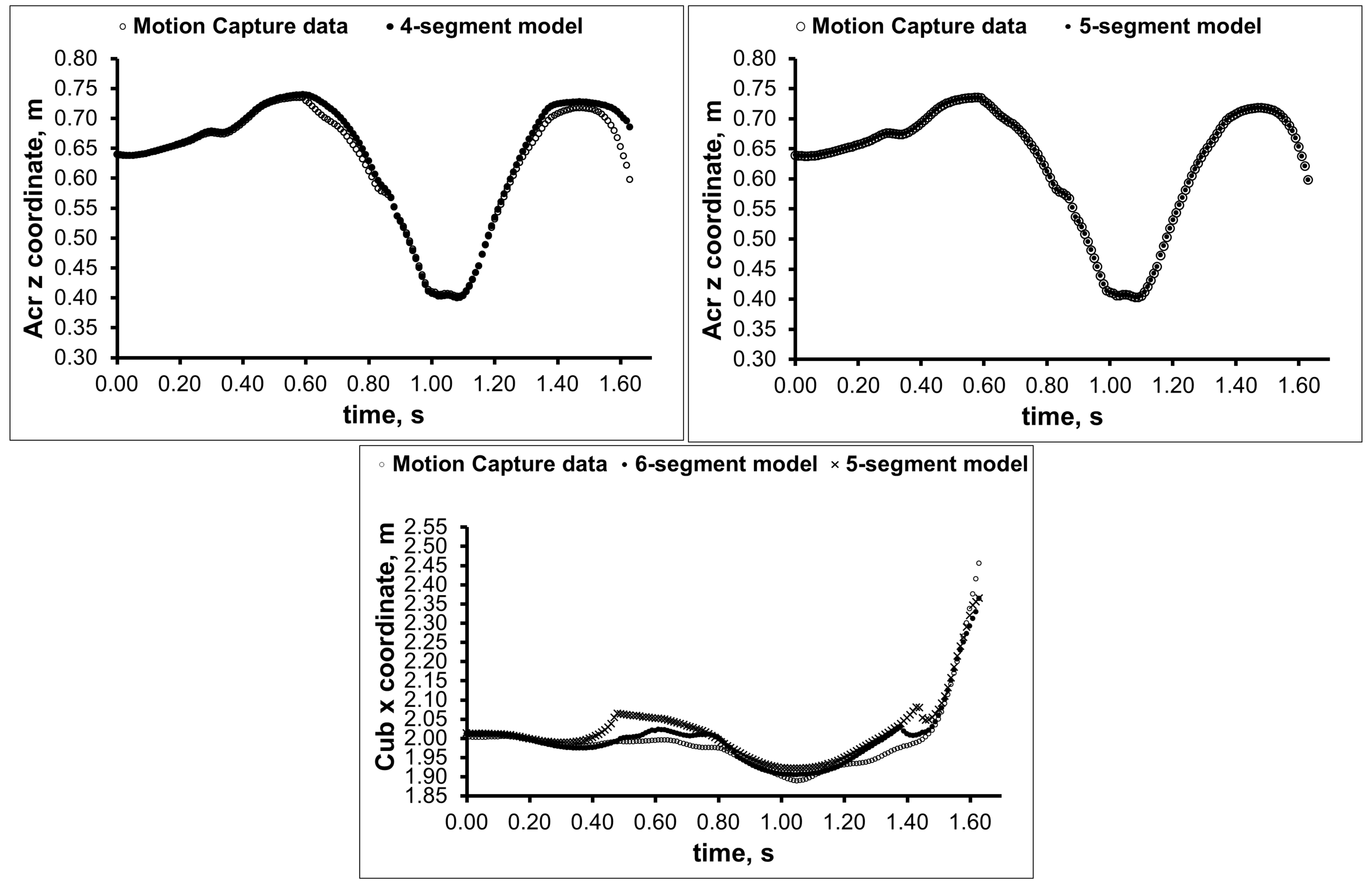

Figure 2. Comparison of model predicted and reference data.

4-segment model (top left), 5-segment model (top-right), 5- and 6- segment models (bottom).

It was possible to simulate the movement adequately without hand and foot segments (5- and 7-segment models), however, adding the hand segment (6-segment model) improved the simulation. Adequate movement simulation with 7-segment model is possible only if one more DOF is added in point Cox – torso transition relative to the sled's longitudinal axis.

During the initial start phases in the sport of luge movement of legs and arms is essentially three-dimensional; therefore modelling in-plane is an expected simplification. Nevertheless, the developed models can simulate the movement realistically in one plane. From the practical application perspective the planar models can be used as a first step in more sophisticated 3D modelling of the start phase in luging. As standalone models they can be used as a visualization tool in movement optimization procedure. The developed models are purely kinematically driven, as no force data was available to use as drivers. Deriving kinetic data from movement simulation is theoretically possible, but validation of the results is challenging as long as no reference measurements are available..

Conclusions

During the initial start phases in luging athlete's torso and sled are can be modelled accurately enough in one plain. One-segment torso is not satisfactory to model the initial phases of start in the sport of luge, and two-segment torso model is required. Modelling of arm and leg segments in a plane is a simplification. Force measurements can be obtained from the constructed model, but validation of these data is not currently possible.

References

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