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Kinetics of hula hooping: An inverse dynamics analysis

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Abstract

This paper involved a biomechanical analysis of lower limb joint coordination during hula hooping. A lower extremity inverse dynamics model that incorporated kinematic input and force platform data was developed to compute the angular velocities, moments about and powers produced at the lower extremity joints. The abductor moments and powers were discovered to be paramount in maintaining hoop oscillations, as demonstrated consistently in the three study participants. However, hula hooping was demonstrated to be variable in terms of the involvement of flexor and extensor moments and powers of the ankle, knee and hip joints, resulting in the adoption of varying strategies by each of the three participants.

PsycINFO classification: 2330

Keywords: Inverse dynamics; Biomechanics; Kinesiology; Moment powers; Mechanical work

1. Introduction

Little scientific attention has been paid to the complex task of hula hooping. In fact, the only systematic research to date was the descriptive kinematic analysis offered by Balasubramaniam and Turvey (2004). These authors applied dynamical systems theory to demonstrate that only two coordinative modes were sufficient to maintain the hoop's oscillations. The current paper examines hula hoop performances by applying inverse

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dynamics to yield additional information concerning what moments of forces of the lower extremity are necessary to sustain motion of the hula hoop.

Hula hooping is a complex task, the functional goal being to keep a hoop in continuous oscillation parallel to the ground via coordinated body movements (Balasubramaniam & Turvey, 2004). The physical basis of hula hooping is the generation and conservation of angular momentum. In short, the performer must exert regulated impulses to create a state of dynamic hoop equilibrium. Two requisite conditions need be satisfied to sustain the equilibrium state. First, a vertical component of the exerted impulse necessarily opposes the force of gravity and secondly, a simultaneous horizontal component maintains the angular motion of the hoop (Balasubramaniam & Turvey, 2004).

The work of Balasubramaniam and Turvey (2004) performed a decompositional analysis of hula hooping kinematics, using a Karhunen–Loève (K–L) transform, to outline the coordinative modes of limb motion which best describe hula hooping. Succinctly, the K–L transform was used to compute orthogonal eigenvectors that characterized the spatiotemporal patterning of the lower limb joints involved in hula hooping. The more prominent motions that characterized hula hooping explained greater variance (for a detailed explanation of principal component analysis in human movement analysis see Daffertshofer, Lamoth, Meijer, & Beek, 2004). The K–L technique revealed dynamic equilibrium was sustained through concurrent oscillatory motions of the hips, knees and ankles, thereby satisfying the characteristic functional constraints of the task. The analysis revealed two principle processes operated to sustain oscillatory motion, the most prominent of which was the fore-aft motion of the hips that sustained the hoop′s angular motion. Of secondary importance was the mechanism controlled at the knee, which created a vertical component to oppose the force of gravity (Balasubramaniam & Turvey, 2004).

The formation of movement trajectories that characterize hula hooping is extremely complex. This complexity is exacerbated because the relation between joint trajectories and the position of end effectors is ambiguous (Feldman, 1986; Lacquaniti & Soechting, 1982; Polit & Bizzi, 1978). Researchers refer to this phenomenon as the equivocality principle (Bardy, Marin, Stoffregen, & Bootsma, 1999; Turvey, Fitch, & Tuller, 1982) which implies that the control of motion cannot be based directly on kinetic, neural, or sensory information (Bardy et al., 1999). Whereas the dynamical systems approach was concerned with describing the abstract kinematic patterning of the limbs in maintaining hoop oscillations, it did not describe how these movement patterns were produced. Therefore, at present little is known about individual joint contributions to the overall coordinative modes or patterns of motion that characterize hula hooping, leaving ambiguity and room for interpretation. Given the equivocal relationship between joint trajectories and the movement of end effectors, the physical complexity of hula hooping and the linked nature of the lower limbs, it is hypothesized that individual joint contributions to the overall kinematic patterning of the lower limbs will vary in maintaining hoop stability. The hypothesis will be tested using an inverse dynamics analysis, which computes the joint moments and moment powers underlying motion. Thus, the objective of the present research was to reveal the kinetic equivalent of existing dynamical systems research to determine whether the approaches yield complementary conclusions, thereby culminating in a more comprehensive understanding of hula hooping. In short, we sought to determine whether inverse dynamics could further our understanding of hula hooping by revealing the contribution of the individual joint moments to the maintenance of dynamic equilibrium.