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SUBJECT-SPECIFIC TRUNK MUSCULOSKELETAL MODELING: CHARACTERISTICS, VALIDATION, AND APPLICATIONS

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Summary: Due to limitations, cost and invasiveness of measurements, musculoskeletal (MS) models are recognized as crucial tools in improving our understanding of functional biomechanics of human articulations in intact and perturbed conditions. Here a trunk MS model is evaluated, validated and applied in various activities. Using the subject-specific model accounting (based on scaling protocols and datasets in the literature) for variations in age, sex, body weight and body height, the effects of motion segment modeling and their positioning on muscle forces and spinal loads are evaluated. Each motion segment is represented either as a shear deformable beam or a spherical joint with/without linear/nonlinear stiffness properties. Model estimations are compared with kinematics in our passive finite element model as well as recorded EMGs in 19 volunteers during maximum voluntary exertions in all directions and symmetric lifting of loads at different heights/magnitudes. Finally, regression equations to estimate compression and shear forces at the lowermost L4-S1 levels are developed for the lifting tasks. Nonlinear deformable beams and spherical joints with offsets from 2 mm anterior to 4 mm posterior to the disc center predicted more accurate kinematics (versus the passive model) and spinal loads (versus in vivo IDP measurements) although spherical joints failed to accurately estimate axial displacements. Shifting joints posteriorly in general increased spinal loads (up to 17% in compression and 26% in shear) and delayed flexion relaxation (by 40 deg) during forward flexion. For a unique estimation of muscle forces and spinal loads, passive properties should increase as joint models shift posteriorly from the center of reaction. The trunk maximum exertion moment in both sexes was highest in extension (236 Nm in males and 190 Nm in females) and least in left axial torque (97and 64 Nm). Maximum muscle stress was computed at 0.80±0.42 MPa and varied among muscles. Overall, good agreements were found between computed forces and recorded EMGs. Regression equations predicted spinal loads in satisfactory agreement with IDP measurements (r=0.92). Spinal loads were most influenced by changes in trunk rotation, body weight and load magnitude/lever arm and least by body height and sex.
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