The 3D Biomechanical Model of Gymnast on Parallel Bars to Promote Highly Difficult Gymnastic Movements

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The long swing gymnastic movements under the parallel bars are highly difficult movements compared to other the movements on parallel bar apparatus. To minimize the verity of execution errors, introduced by the Federation of International Gymnastics, such as lack of extension at horizontal regrasping after saltos and uncontrolled regrasping, with around 75% shoulder injuries based on these elements in China, the 3D biomechanical model of gymnast has been introduced as a coaching tool. Standard Lagrange dynamic equations are used to derive the dynamic equations of hands, upper arms, lower arms, head, 'upper Torso+lower Torso', thighs, shanks and feet as 14 segments models. Standard Chinese anthropometric measurements are considered to find the characteristics of 14 segment body models. Gleno-Humaral joints of gymnast are used as a model with massless spring-dampers. Hence the kinematics on the frontal frame of gymnastic-parallel bars system are observed. The 3D mathematical model was designed using four massless spring dampers and two point masses to observe the dynamic properties of wooden bars. The Kene's procedure was used to derive the system's dynamical equations. Finally, the simulation of the 3D biomechanical model of the gymnast on the parallel bars was designed to predict technically accurate movement patterns of the long swing gymnastic movements with all necessary kinetics: maximum muscle torques for 58 kg gymnast (Shoulder 18.11 N.m, Hip 378 N.m, Knee 111.3 N.m), kinematics of the gymnast-parallel bars system (angular velocities are arm 400.01 deg.s^{-1}, thighs -452.35 deg.s^{-1} and shank 352 deg.s^{-1}) and maximum displacement of Acromion from Cervical Vertebra (7th) 0.0349 m on sagittal plane in the dynamic situation. Similarly, these values have been predicted for physically prepared newcomers for long swing gymnastic movements (for 70 kg player: Shoulder 20.10 N.m, Hip 424 N.m, Knee 132.4 N.m). According to these findings, movement pattern of the long swing movements was adjusted to minimize the execution errors and injuries. This 3D biomechanical model can demonstrate the role of elastic energy of parallel bars to promote highly executed long swing gymnastic movements. Hence, coaches and players can use this 3D biomechanical model of gymnast for their coaching-training process of highly difficult long swing gymnastic movements on parallel bars.

Keywords: 3D biomechanical model of gymnast, dynamic strain, bars of 'parallel bars', long swing gymnastic movements, shoulder joint