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Musculoskeletal injuries of the human limbs are commonly associated with strenuous and high-risk activities in sports and recreations. The human knee (and other joints in the lower and upper limbs in general) is free to move in the sagittal plane (flexion/extension), injuries to the knee usually do not occur in sagittal major-axis movements. In contrast, knee movement about the off-axes including tibial rotation and valgus/varus (inversion/eversion and internal/external rotations for the ankle) is much more limited. Injuries to the knee and other joints often occur under excessive *off-axis* loadings, as is evidenced by the highest incidence of ACL injuries occurring in pivoting sports (involving tibial rotation and valgus/varus loadings at the knee) for example. Although 3-D multi-axis biomechanical analyses have been used in investigating various physiological and pathological conditions, there is a lack of translational work to help train/improve off-axis neuromuscular control more effectively and there is a lack of practical and convenient rehabilitative equipment and exercise programs to train human subjects in controlling risky off-axis movements. Almost all existing exercise/rehabilitation equipment (e.g., treadmill, bicycles, elliptical machines, stepper, stair climber and leg press) and related trainings focus on sagittal major-axis movements.

RECOMMENDATION 1:

Translate 3-D multi-axis biomechanical studies on various human joints and muscles into more focused and potentially more effective off-axis training and rehabilitation protocols and address the key factors related to musculoskeletal injuries.

RECOMMENDATION 2:

To conduct 3-D multi-axis biomechanical evaluations and diagnose the subject's specific weakness/impairment, including the off-axis neuromuscular and biomechanical properties that may be difficult to do during manual exaiminations, and conduct subject-specific training using the off-axis training systems described below.

RECOMMENDATION 3:

Develop practical off-axis training systems and conduct off-axis neuromuscular training using the off-axis training systems in the rehabilitation following lower-limb (knee, ankle) injuries, and in outcome evaluations including off-axis neuro-mechanical properties associated with the injuries. The off-axis training systems should provide close-chain-training involving multiple joints and with the major-axis movement training combined with off-axis training to make the movement/training more practical and functionally relevant.

In summary, 3-D multi-axis biomechanical analyses should be translated from research laboratories to exercise and clinical practice to benefit human subjects. Practical off-axis training systems will potentially provide a powerful platform to help human subjects improve their off-axis neuromuscular control, reduce potential musculoskeletal injuries, and have more effective post-injury rehabilitation.