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Kinetic **N**euromuscular **E**ffective **E**xercise System

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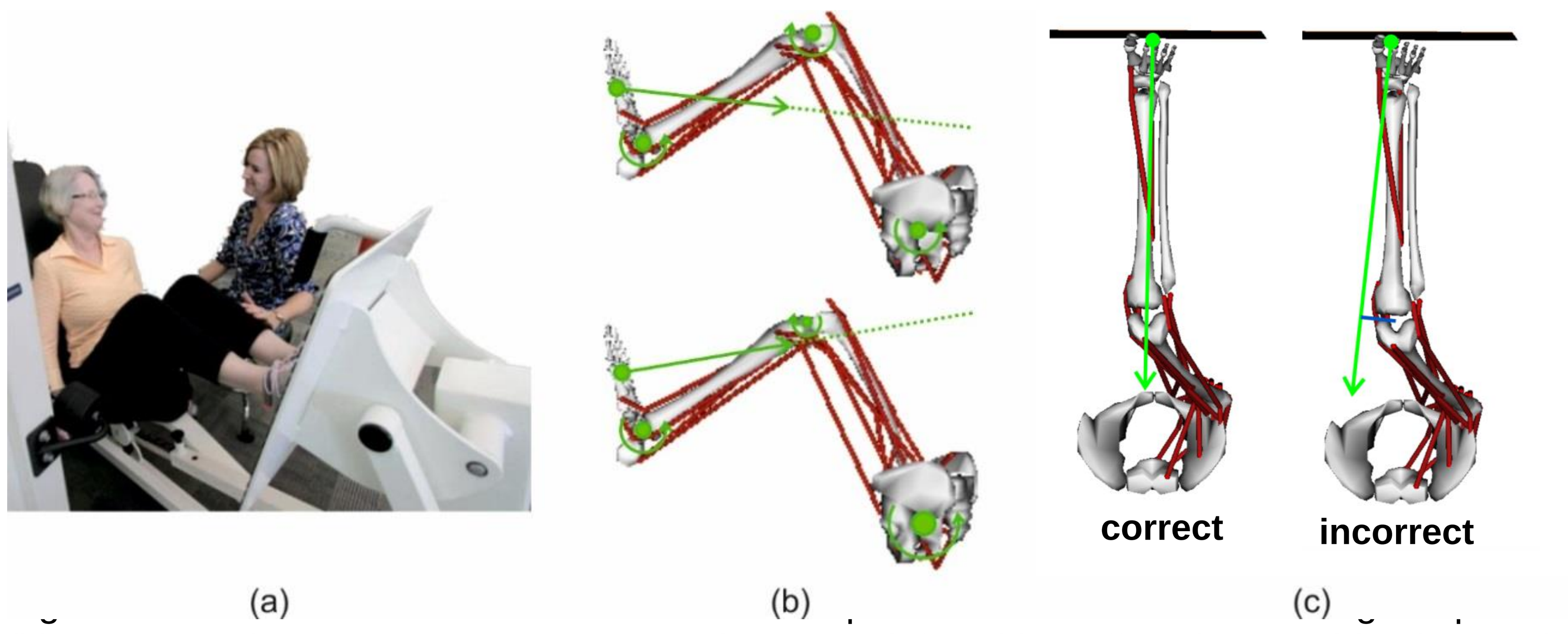
Muscle strength training of the leg extensors is an important intervention for aging people to recover from or prevent the development and progression of musculoskeletal disorders. However, there is a trade-off between training effectiveness and training-induced damage. Effective muscle strengthening requires high muscle forces on one side. On the other side, the control of these high forces is necessary to avoid non physiological loading on the musculoskeletal system and to guarantee a safe training.



(b). Inappropriate postures or varus and valgus deformities affect knee adduction and abduction moments in frontal plane, i.e. knee joint loading (c).

Current training devices usually use the horizontal force, movement velocity and range of motion as the only indicators for joint loading and training (1a). However, a similar horizontal force does not necessarily imply similar muscular effort for the knee extensor muscles. Due to the different direction of the force vector, the joint moments for the ankle, knee and hip and thus the contribution of the leg extensor muscles differ considerably (1b). The plate reaction force vector in frontal plane highlights a cause for a potential training-induced damage (1c). High external knee adduction moments reject high compressive forces acting on the medial knee compartment and are supposed to foster osteoarthritis development and progression.

Thus, training in the leg press with patients and elderly people should focus to reduce knee adduction moments.

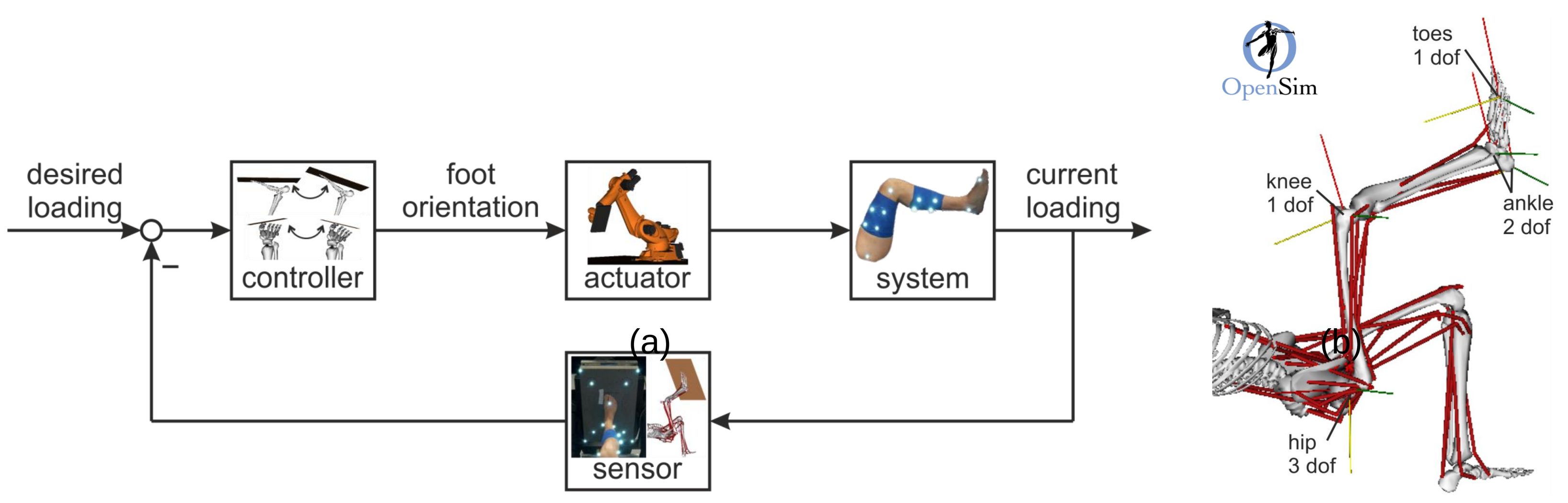


Fig. 2: (a) Control loop with the joint loading as controlled and foot orientation as manipulated variable. (b) The loads are estimated with a sensor system consisting of a force plate, an optical motion tracking system and a musculoskeletal model (OpenSim). First experiments and mathematical simulations confirmed the potential in improving effectiveness and safety of leg press exercise by influencing joint loadings with the orientation of the foot plate in sagittal and frontal plane.

Fig. 3: Visualization of the novel robotic leg press training device. The actuator (KUKA KR 270 R2700 ultra) of the training device should be able to control the resistive force, movement velocity and range of motion by applying individual training trajectories.

KNEE is able to estimate loadings on target tissues and minimize non-physiological loading though the application of a control-loop (fig. 2) and will considerably improve

- training efficiency
- training safety
- training measurability
- training autonomy
- facilitation of training evolution
  (new training concepts easily integrated via software update)

Applications:

- **Orthopedics:** controlled and safe neuromuscular training after musculoskeletal disorders/surgery/injuries
- **Athletics:** functional strength training, motor control, controlled high intensive eccentric training
- **Neuro:** motor control and proprioceptive training
- **Metabolic diseases:** improve cardio-pulmonary condition, increase muscle mass (important in the prevention and treatment of diabetes)
- **Elderly:** safe muscle strength training to prevent the development and progression of musculoskeletal disorders

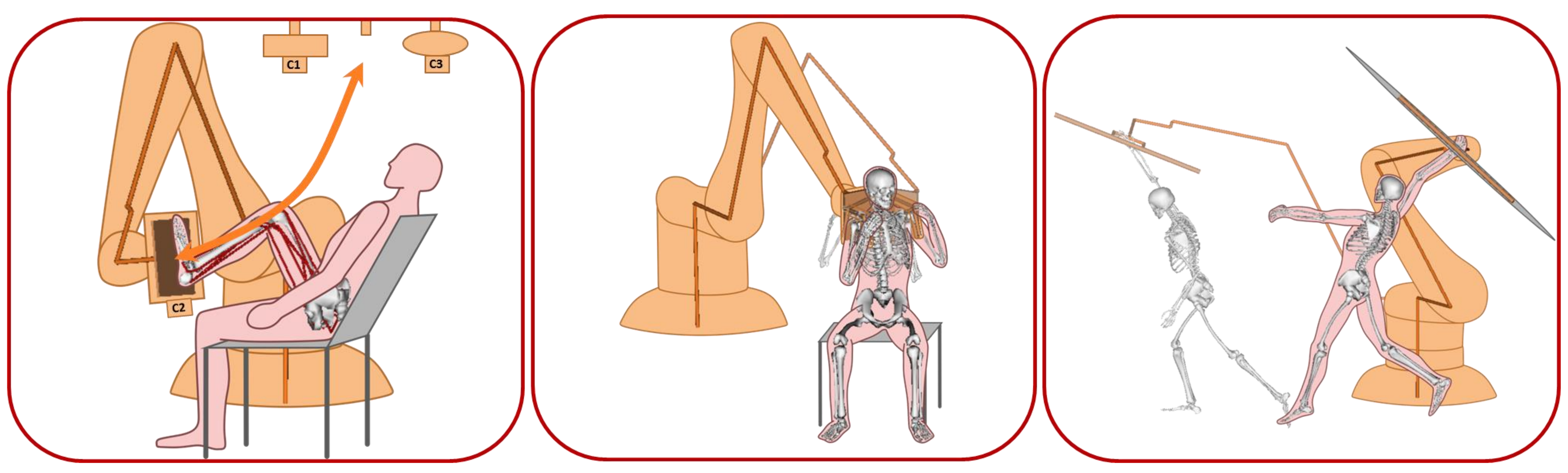


Fig. 4: The concept can be adapted to many other application (e.g. training of muscles surrounding the spine and shoulder). Self(re)configuration as proven technology of industrial automation should be implemented.

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