- In this study, biarticular exoskeleton assisting hip and knee has been proposed and compared to another typical monoarticular exoskeleton.
- We modeled the proposed exoskeletons mechanism through musculoskeletal simulations to study the performance of the device and its difference with the monoarticular exoskeleton along with analyzing their effect on the assisted musculoskeletal models.
- At the first phase of this study, We conducted simulations with ideal exoskeletons to the joints to verify the modeling, and to study the performance of device under ideal condition. This simulations showed that:
    - Despite the same metabolic reduction effect, the devices have different power consumption.
    - The biarticular exoskeleton had more even power distribution between the different load conditions.
    - Loading subject with a heavy load changed the profiles of devices only by the magnitude and timing and the trajectories did not changed considerably.
    - The device affected the hip abduction and ankle indirectly.
    - The reaction forces and moments of assisted and unassisted joints were significantly changed and devices had slightly different effect on the reaction moments of the knee joint.

- we organized another stage at this study in which we introduce a novel Pareto simulations framework to conduct reliable comparisons among different configurations of the exoskeletons in their optimal configurations by taking advantage of Pareto optimization methods. Through this phase of study we showed that:
    - Both constrained devices can provide practically the same assistance delivered by the ideal exoskeletons using lower power in both actuators.
    - Although both devices showed practically the same performance, the optimal configurations of these devices are considerably different and have different effect on the muscle activations of assisted subjects.
    - The optimal monoarticular exoskeletons tended operate in the high peak torque regions comparing to the biarticular exoskeleton especially on the hip joint.
    - The biarticular device showed more robust performance by loading subjects than the monoarticular device.

- The regeneration could considerably affect the power consumption of devices.
- The monoarticular hip actuator showed high within optimal devices and between load condition variations complicating designing a general device.
- through joint reaction forces and moments analyses, we showed the resemblance of the reaction forces and moments of joints assisted with constrained devices directly and indirectly, to reaction forces and moments of subjects assisted with ideal devices. Nevertheless, devices had different effect on the assisted joints during the stance phase.

- To investigate the effect of optimal devices inertial properties, obtained from the Pareto simulations, on the metabolic rate of assisted subjects, we adopted the model developed for estimating the metabolic rate of subjects mounted with the additional masses and performed offline simulations.
- Along with these simulations, we proposed a modification for the augmentation factor ,developed by Mooney et al to estimate metabolic power change due to carrying the exoskeleton to assess the optimal devices performance:
    - Through this phase of study, we showed that both devices affected considerably by considering their inertial properties and this effect was more severe on the monoarticular device due to its kinematic design.
    - Most of optimal biarticular devices on pareto front remained optimal after reflecting their inertial properties effect on the metabolic rate of assisted subjects.
    - Although high torque was required for monoarticular to have positive effect on the subjects, non of high torque devices showed optimal performance.
    - We showed that keeping the knee actuator near to the hip joint or grounding it to the shank instead of thigh can improve the performance of the monoarticular device notably.