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% Stiffness Method

%\paragraph{Joint stiffness analysis.} To analyze the effect of the purposed devices on %the assisted joints' stiffness, we characterized the moment-angle relation of the hip %and knee joints. We analyzed then their stiffness in the phases that the hip and knee %moment-angle curves exhibit nearly linear behavior by linear fitting in which the slope %of the line represents the estimated stiffness of the joints. This stiffness is called %quasi-stiffness, which is defined as stiffness that best describes the overall stiffness %property of a joint during a specific locomotion task %\cite{152,153,155,156,157,159,162,163,164,165,166}. It should be noted that the %quasi-stiffness is characterizing the linear phases of locomotion, and it needs to be %distinguished from the passive and active stiffness of a joint \cite{167,168,169}.

%This method has been previously employed to characterize the stiffness of the lower limb %joints in different locomotion tasks and scenarios %\cite{152,153,155,156,157,159,162,163,164,165,166} and designing assistive devices %\cite{154,158}, and we closely followed the method developed by Shamaei et al. %\cite{155,156} for extracting the quasi stiffness of the hip and the knee joints.\\

%Analysis of the moment-angle curve of the hip joint during normal walking shows that the %moment and angle have nearly linear association during the terminal stance phase %\cite{152}. The terminal stance phase of the hip joint is composed of the extension %stage, which begins with the onset of this phase and ends by hip reaching its maximum %extension, and the flexion stage starting with maximum hip extension and extends into %the initial swing phase \cite{156}. Throughout the terminal stance phase, the hip joint %experiences high energy storage during the extension and release during the flexion %stage in which the mechanical function of the hip joint is significantly prone to %distortion by any disturbance or gait abnormality \cite{156}.\\

%The knee joint-moment curve shows this linear relationship during the loading response %and mid-stance phases, which are called the weight acceptance phase jointly \cite{155}. %The importance of this phase is that the knee joint provides a significant amount of %moment during the weight acceptance stage, making the joint highly predisposed to %disruption by any external disturbances or musculoskeletal abnormalities similar to the %hip joint \cite{155,156,160}. The weight acceptance phase is composed of the flexion %stage starting by heel contact and extends to maximum flexion of the first knee flexion %arc, followed by the extension stage that ends when the knee joint reaches to the maximum %extension of its first extension arc\cite{155}.\\

%These linear phases of the hip and knee joints were extracted for each subject by %customizing the general duration of the phases \cite{161} for each subject in both load %conditions (i.e., {\it loaded} and {\it noload} conditions) and assistance conditions ( %i.e., unassisted and assisted conditions) and the stiffness of the joints were %characterized to investigate the effect of each assistive device on the stiffness of the %joints.

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