S2: Muscle Model

Fig. S2.1 shows the three element Hill-type muscle that was used in this work. It consists of a contractile element, parallel elastic element and series elastic element. Its input is the stimulation, \( u \), and the states are the activation, \( a \), and the contractile element length, \( l_{CE} \). The force in the contractile element is determined as follows:

\[
F_{CE} = af(l_{CE})g(v_{CE})F_{max}
\]

where \( f(l_{CE}) \) is the force-length relationship, and \( g(v_{CE}) \) is the force-velocity relationship.

The parallel and series elastic elements are modeled as quadratic springs. Their force are found based on the model presented by McLean et al. [1]:

\[
F(l) = \begin{cases} 
  k_1(l - l_{slack}) & \text{if } l \leq l_{slack} \\
  k_1(l - l_{slack}) + k_2(l - l_{slack})^2 & \text{if } l > l_{slack}
\end{cases}
\]

where \( l \) denotes the length of the element and \( l_{slack} \) the slack length. \( k_1 \) and \( k_2 \) are stiffness constants. \( k_1 = 0.01 \) \( F_{max}/m \) represents a small linear stiffness, which was added to aid the optimization. It is equal to. \( k_2 \) is equal to the following:

\[
k_2(PEE) = \frac{F_{max}k_{PEE}}{l_{CE(OPT)}^2}
\]

\[
k_2(SEE) = \frac{F_{max}}{(u_{max}l_{CE(OPT)})^2}
\]

where \( k_{PEE} = 1 \) and \( u_{max} = 0.04 \) are dimensionless constants.

The muscle mass, \( m_{mus} \), was determined using the maximum isometric force and the optimal fiber length:

\[
m_{mus} = \frac{F_{max}}{\sigma}l_{CE(OPT)}
\]
where $\sigma = 25 \text{ N/cm}^2$ is the muscle-specific stress and $\rho = 1059.7 \text{ kg/m}^3$ is the density of muscle.

Tab. S2.1 shows the maximum isometric force $F_{\text{max}}$, optimal fiber length, $l_{CE(OPT)}$, width of the force-length curve, the slack length of the parallel elastic element (PEE) and the series elastic element (SEE), the nominal muscle length, $l_m$, and the percentage of fast twitch fibers for each muscle. Several parameters parameters for each muscle. Several parameters were the same for each muscle, the activation time, $T_{\text{act}} = 0.01 \text{ s}$, the deactivation time, $T_{\text{deact}} = 0.03 \text{ s}$, the maximum shortening velocity, $v_{CE(\text{max})} = 12 \frac{l_{CE(OPT)}}{s}$, the maximum force during lengthening, $g_{\text{max}} = 1.5 F_{\text{max}}$, and the normalized hill constant, $A_{\text{hill}} = 0.25$.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>$F_{\text{max}} [N]$</th>
<th>$l_{CE(OPT)}$ [m]</th>
<th>Width</th>
<th>PEE slack $l_{CE(OPT)}$</th>
<th>SEE slack [m]</th>
<th>$l_m$ [m]</th>
<th>% FT fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iliopsoas</td>
<td>1500</td>
<td>0.102</td>
<td>1.298</td>
<td>1.2</td>
<td>0.142</td>
<td>0.248</td>
<td>0.5</td>
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<tr>
<td>Gluteals</td>
<td>3000</td>
<td>0.2</td>
<td>0.625</td>
<td>1.2</td>
<td>0.157</td>
<td>0.271</td>
<td>0.45</td>
</tr>
<tr>
<td>Hamstrings</td>
<td>3000</td>
<td>0.104</td>
<td>1.197</td>
<td>1.2</td>
<td>0.334</td>
<td>0.383</td>
<td>0.35</td>
</tr>
<tr>
<td>Rectus Femoris</td>
<td>1200</td>
<td>0.081</td>
<td>1.443</td>
<td>1.4</td>
<td>0.398</td>
<td>0.474</td>
<td>0.65</td>
</tr>
<tr>
<td>Vastus</td>
<td>7000</td>
<td>0.093</td>
<td>0.627</td>
<td>1.4</td>
<td>0.223</td>
<td>0.271</td>
<td>0.5</td>
</tr>
<tr>
<td>Gastrocnemius</td>
<td>3000</td>
<td>0.055</td>
<td>1.039</td>
<td>1.2</td>
<td>0.42</td>
<td>0.487</td>
<td>0.5</td>
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<tr>
<td>Soleus</td>
<td>4000</td>
<td>0.055</td>
<td>1.039</td>
<td>1.2</td>
<td>0.245</td>
<td>0.284</td>
<td>0.2</td>
</tr>
<tr>
<td>Tibialis Anterior</td>
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<td>0.082</td>
<td>0.442</td>
<td>1.2</td>
<td>0.317</td>
<td>0.381</td>
<td>0.25</td>
</tr>
</tbody>
</table>
References
