Tutorial 3

Montag, 14. November 2022 14:51

22-23_Int... (1)

Introduction to Biomechanics VU 317.043

Tutorial 3

8.11.2022

Leg – joint reaction forces and moments

Given figure 1 below calculate the joint reaction forces at the knee and the hip at the 50% stance phase of the gait cycle.

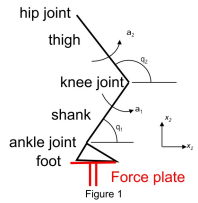


Figure 1

Use the following data for your calculations:

Anthropometric data

Limb segment	Segment length	Segment mass*	Centre of mass**	Radius of gyration r_g #
Thigh	32 cm	0.1 M	0.433	0.323
Shank	43 cm	0.0465 M	0.433	0.302

* Expressed as a fraction of the total body mass, M, where M = 70 kg
** Expressed as a fraction of the total segment length, measured from the proximal end of the segment
# Expressed as a fraction of the segment length and for rotation around the center of mass

Thigh and shank kinematic data

% of stance phase of gait cycle	Shank angle Θ_1[°]	Thigh angle Θ_2[°]	Shank acceleration α_1 [rad·s-2]	Thigh acceleration α_2 [rad·s-2]
0	108.4	109.4	-32.87	0.13
10	100.3	108.4	-2.78	3.58
20	91.9	106.9	18.47	-28.36
30	86.5	101.2	7.87	-4.84
40	82.5	94.3	-0.22	7.81
50	78.7	88.7	-0.22	0.01
60	74.9	83.1	-2.99	-1.71
70	70.2	77.5	-13.88	11.95
80	63.2	73.8	-13.69	16.49
90	53.6	73.4	-8.16	27.13
100	42.9	78.1	25.25	30.36

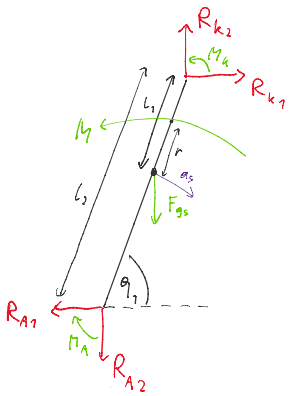
Ankle reaction forces and muscle moments for the foot segment

% of stance phase of gait cycle	Reaction force, x_1 direction [N]	Reaction force, x_2 direction [N]	Muscle moment, [Nm]
0	-60.1	-101.7	-1.7
10	109.1	-572.1	6.9
20	135.1	-728.3	-0.5
30	58.3	-628.0	-6.6
40	27.7	-456.0	-18.7
50	21.6	-453.5	-30.3
60	-2.6	-534.2	-45.4
70	-49.9	-670.2	-71.2
80	-107.9	-744.2	-89.7
90	-130.5	-555.8	-68.6
100	-32.9	-125.7	-12.3

Shank and thigh acceleration data

% of stance phase of gait cycle	Shank acceleration x_1 direction [ms-2]	Shank acceleration x_2 direction [ms-2]	Thigh acceleration x_1 direction [ms-2]	Thigh acceleration x_2 direction [ms-2]
0	-5.87	2.26	-0.31	4.29
10	-4.01	2.75	-4.05	2.63
20	-6.62	-1.74	-4.85	-2.32
30	-3.89	0.40	-4.13	-1.01
40	0.82	-0.53	-0.65	-2.12
50	1.71	-0.05	1.15	1.46

Shank:



$x: \quad R_{K1} - R_{A1} = m_S \cdot a_{S1}$

$R_{K1} = m_S \cdot a_{S1} + R_{A1} = 25,54\,N$

$y: \quad R_{K2} - R_{A2} - F_{gs} = m_S \cdot a_{S2}$

$R_{K2} = m_S \cdot a_{S2} + R_{A2} + m_S \cdot g = -427,67$

$M: \quad I_S = m_S r^2$

$M = I_S \cdot \alpha_1 = m_S r^2 \alpha_1 = -0,012\,Nm$

$M_1 = R_{A2}(l_2 - l_1)\cos q_1 - R_{A1}(l_2 - l_1)\sin q_1 = -26,83\,Nm$

$M_2 = R_{K2} l_1 \cos q_1 - R_{K1} l_1 \sin q_1 = -20,76\,Nm$

$M = M_K - M_A + M_1 + M_2$

$M_K = m_S r^2 \alpha_1 + M_A - R_{A2}(l_2 - l_1)\cos q_1 + R_{A1}(l_2 - l_1)\sin q_1 - R_{K2} l_1 \cos q_1 + R_{K1} l_1 \sin q_1 = 76,68\,Nm$

$m = 70kg$

$m_S = 0,0465\,m$

$a_{S1} = 7,27\ m/s^2$

$a_{S2} = -0,95\ m/s^2$

$R_{A1} = 27,6\,N$

$R_{A2} = -453,5\,N$

$r = 0,302\,l_2$

$l_2 = 0,43\,m$

$\alpha_1 = -0,22\ rad/s^2$

$l_1 = 0,433\,l_2$

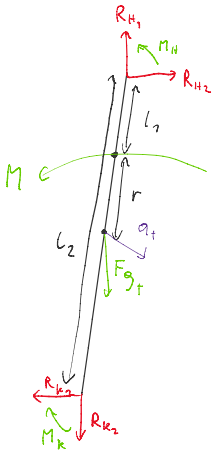
$q_1 = 78,7°$

$M_A = -30,3$

% of stance phase of gait cycle	Shank acceleration x_1 direction [ms^{-2}]	Shank acceleration x_2 direction [ms^{-2}]	Thigh acceleration x_1 direction [ms^{-2}]	Thigh acceleration x_2 direction [ms^{-2}]
0	-5.87	2.26	-0.31	4.29
10	-4.01	2.75	-4.05	2.63
20	-6.62	-1.74	-4.85	-2.32
30	-3.89	0.40	-4.13	-1.01
40	0.82	-0.53	-0.65	-2.12
50	1.21	-0.95	1.15	-1.46
60	0.45	1.62	1.16	0.67
70	3.58	1.43	3.58	0.20
80	9.13	0.09	7.98	-1.12
90	14.31	0.82	9.09	-0.68
100	8.47	1.66	-2.10	3.27

Hint Reaction forces and muscle moments measured via a force plate or calculated for a certain segment need to be inverted to be valid for the next segment.

Thigh:



x: $R_{H_1} - R_{K_1} = m_t \cdot a_{t_1}$

$R_{H_1} = m_t \cdot a_{t_1} + R_{K_1} = 33,59\,N$

y: $R_{H_2} - R_{K_2} - F_{g_t} = m_t \, a_{s_2}$

$R_{H_2} = m_t \cdot a_{t_2} + R_{K_2} + m_t \cdot g = -366,22\,N$

M: $I_t = m_T r^2$

$M = I_t \cdot \alpha_2 = m_T r^2 \alpha_2 = 0,00075\,Nm$

$M_1 = R_{K_2}(l_2 - l_1)\cos q_2 - R_{K_1}(l_2 - l_1)\sin q_2 = -6,38\,Nm$

$M_2 = R_{H_2} l_1 \cos q_2 - R_{H_1} l_1 \sin q_2 = -5,8\,Nm$

$M = M_H - M_K + M_1 + M_2$

$M_H = m_s r^2 \alpha_1 + M_K - R_{K_2}(l_2 - l_1)\cos q_2 + R_{K_1}(l_2 - l_1)\sin q_2 - R_{H_2} l_1 \cos q_2 + R_{H_1} l_1 \sin q_2 = 28,86\,Nm$

$m_t = 0,1\,m$

$a_{t_1} = 1,15\,m/s^2$

$a_{t_2} = -1,96$

$R_{K_1} = 25,54\,N$

$R_{K_2} = -424,67\,N$

$r = 0,323\,l_2$

$l_2 = 0,32\,m$

$\alpha_2 = 0,01\,rad/s^2$

$l_1 = 0,433\,l_2$

$q_2 = 88,7$