1. What is the net joint moment, in the static case, at the ankle joint about the subtalar joint axis (the circle with a dot represents a vector perpendicular to the plane of the drawing) given the situation in the sketch?

What is the net joint moment at the knee joint in varus valgus direction?

\[ F_{\text{vert}} = 1800 \text{ N} \]
\[ F_{\text{hor}} = 300 \text{ N} \]
\[ m_{\text{foot}} = 1.4 \text{ kg} \]
\[ l_{\text{sub}} = 0.08 \text{ m} \]
\[ m_{\text{leg}} = 4.0 \text{ kg} \]

This calculation is basically a continuation of Question 1 from the previous worksheet, but in a different plane of movement.

The formula is also found in the solutions from the last worksheet. The equation of motion requires the sum of all moments acting on the foot segment to equal the rotational acceleration of the foot \( (\alpha) \) times its moment of inertia \( (I) \):

\[ \sum M_{\text{foot}} = I * \alpha \]

In the static case we know \( \alpha = 0 \); so we only need the external moments given by the GRF. There are two ways of doing this: either calculate the moment by the horizontal and vertical GRF components separately, but then we need to know their distances to the axis of rotation. In this case the lever arm of the resultant GRF to the joint center is given. So we just need to calculate \( F_{\text{ground}} \):

\[ F_{\text{ground}} = \sqrt{F_{\text{vert}}^2 + F_{\text{hor}}^2} \]

\[ F_{\text{ground}} = 1824 \text{ N} \]

With that one can calculate the moment generated by the GRF \( (M_{\text{GRF}}) \):

\[ M_{\text{GRF}} = l_{\text{sub}} * F_{\text{ground}} \]

\[ M_{\text{GRF}} = 145.9 \text{ Nm} \]

(It has to be considered that the foot is pulled down by gravity, so there is a moment exerted on the subtalar joint by gravity. This would be \( F_{\text{w(foot)}} \times \text{distance of the foot's center of mass to the joint axis} \). This was not given in this task but it will be very close to the axis and if we assume that it may be 4 cm we can calculate it by \( F_{\text{w(foot)}} = m_{\text{foot}} * g \Rightarrow F_{\text{w(foot)}} = 14 \text{ N} \)

So the moment created by the foot’s weight \( M_{\text{foot}} \) is:

\[ M_{\text{foot}} = F_{\text{w(foot)}} * 0.04 \text{ m} = 0.56 \text{ Nm} \]

This is a very small contribution compared to the 145.9 Nm generated by the external GRF and therefore this simple approach is often used to estimate joint torques by just looking at the GRF vector with respect to the joint location.

What needs to be considered when looking at a moving skeleton?

It would simply be that we need to know \( \alpha \), i.e., the rotational acceleration of the foot in the plane of movement. Given the low mass and moment of inertia of the foot this may not be of great importance in this case, but more so for heavier segments, i.e., the thigh.

The acceleration can only be measured; see examples 5.9 and 5.10 from the text book: Robertson, D.G.E., Caldwell, G.E., Hamill, J., Kamen, G., Whittlesley, S.N. (2004): Research Methods in Biomechanics. Human Kinetics, Champaign, IL
Worksheet for Sport Injuries Lecture 2 – knee injuries.

For the knee joint the resultant GRF could also be used to estimate the torque in varus-valgus direction. So in this case it is a valgus torque. This means that while the foot is in a ‘safe’ situation the knee is in danger.

2. How (much) would the situation change with shoes? Geometry, other effects?

The first thing is that the foot is higher over the ground with the midsole of the shoe between foot and ground. Assuming that the forces would be the same the moment created by the horizontal GRF would increase; and with that the total moment (in the sketch in Question 1 acting in eversion direction) would be reduced. This would not be critical to the ankle as long as the moment would remain an eversion moment.

For the knee it might be beneficial as with setting the foot higher in the drawing will most likely reduce the leverarm at the knee.

However, in the lecture we talked about the cushioning of the shoe. If a soft shoe sole is interspersed it is likely that the shoe would reduce the peak forces at initial contact (have a look at the graphs in the Dayakidis paper). There a high peak force is shown at the beginning of ground contact. So shoes may be beneficial. Then again, many studies have shown that introducing or changing shoes may alter the whole technique of different subjects very individually. But that is very hard to predict.

3. What would be the effect of taping/casting (skinne) at the ankle joint?

Two effects: 1) the foot would be held in a different position such that the placement of the foot as shown in slide 33 may not be as likely. This applies for taping and casting, even if tape may loose its stickiness due to sweating, it may still hold the foot in everted position during swing. 2) increase of stiffness of the joint. Here the effect of a cast/brace is most likely better than taping or soft-braces (see Ubell study).

4. How would a knee cast interfere with this type of movement? E.g.:

As the knee is a hinge joint this kind of cast would most likely not change its position in varus-valgus. Some of these casts can limit the range of movement in flexion and extension (variable locks at the joint of the cast). With that, the knee could be kept in a more flexed position at initial contact. It is not clear what effect this would have on the load distribution within the joint, however, one of the injury mechanisms stated in the literature is landing on an almost straight leg. It is generally believed that knee braces are helpful during early rehabilitation, where the range of motion is not fully regained. If they really able to protect during dynamic sporting activities is not proven.