Basic Biomechanics: Forces at C0-C1 With A Head Forward Position.

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We sometimes wonder about the effect of head forward posture. What kind of biomechanical effect does it have? This is likely to be a consideration in persons with revered or kyphotic curves, or in persons with really poor posture. Because the human head weighs between 8 and 11 pounds or so (we can actually check look-up tables based on the sex and height) the muscles of the neck will have to contract to oppose this forward posture. And, since all forces are opposed by reaction forces, we have, essentially, a three force system: the weight due to gravity, the muscle force, and the joint reaction force. Let’s calculate the compressive force at the atlantoocipital joint. We’ll assume the head weighs 50 N (about 11 lb) and the angle made by the muscle line of action with the horizontal is theta (30 degrees) and that of the joint reaction force is beta (60 degrees).

This is actually a classical statics problem. Assuming the head is being held forward, it must be in equilibrium. The force system acting on it then must be either a parallel one or a concurrent one. If we diagram the problem, we can see that it is a concurrent system, with the three forces converging at O, **Figure 1**.

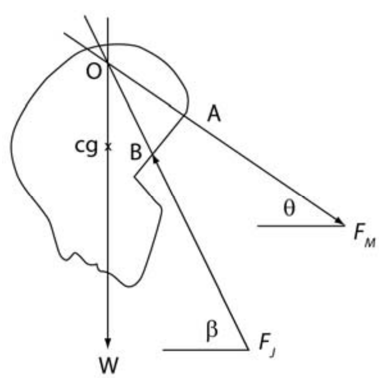

Figure 1. Forces acting through the C0-C1 joint form a concurrent system about O. F_M is the muscle force line of action, B is the joint, cg is the head’s center of gravity, W is the gravity line of action, and F_J is the joint reaction force line of action. (Adapted from Ozkaya N, Nordin M: *Fundamentals of Biomechanics*, 2nd edition, New York, Springer, 1999.)

We draw the weight line W vertically through the head’s center of gravity. The muscle force line of action F_M can be approximated based on muscle anatomy of the chief extensors of the neck. The joint reaction force F_J has to be working through the C0-C1 joint B and it has to pass through the convergence of W and F_M. From this we construct the free-body diagram as a better way of deciding how to solve this problem, **Figure 2**.

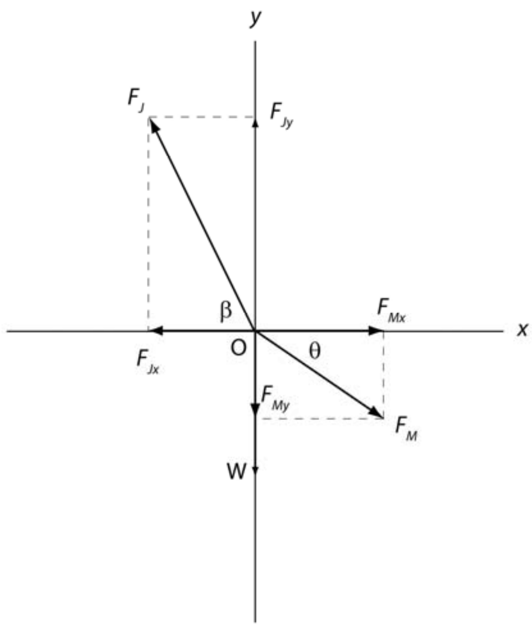

Figure 2. The free-body diagram of Figure 1. (Adapted from Ozkaya N, Nordin M: *Fundamentals of Biomechanics*, 2nd edition, New York, Springer, 1999.)

The two unknown forces, which are, of course, vectors, have been resolved into their Cartesian coordinates. The rectangular components are:

$$\begin{aligned} F_{Mx} &= F_M \cos\theta \\ F_{My} &= F_M \sin\theta \\ F_{Jx} &= F_J \cos\beta \\ F_{Jy} &= F_J \sin\beta \end{aligned} \tag{1.1}$$

The translational equilibrium conditions in the x and y directions will yield:

$$\begin{aligned} \sum F_x &= 0: \quad F_{Jx} = F_{Mx} \\ \sum F_y &= 0: \quad F_{Jy} = W + F_{My} \end{aligned} \tag{1.2}$$

Substituting eq. 1.1 into eq. 1.2:

$$
\begin{aligned}
&F_J \cos\beta = F_M \cos\theta \\
&and \\
&F_J \sin\beta = W + F_M \sin\theta
\end{aligned} \tag{1.3}
$$

Dividing the second by the first of these two to eliminate F_J gives:

$$
\tan\beta = \frac{W + F_M \sin\theta}{F_M \cos\theta} \tag{1.4}
$$

This can be solved now for F_M:

$$
\begin{aligned}
&F_M \cos\theta \tan\beta = W + F_M \sin\theta \\
&F_M \left(\cos\theta \tan\beta - \sin\theta\right) = W \\
&F_M = \frac{W}{\cos\theta \tan\beta - \sin\theta}
\end{aligned} \tag{1.5}
$$

Thus:

$$
F_M = \frac{50}{(\cos 30)(\tan 60) - (\sin 30)} = 50N \tag{1.6}
$$

And from eq. 1.1:

$$
\begin{aligned}
&F_{Mx} = (50)(\cos 30) = 43N \\
&F_{My} = (50)(\sin 30) = 25N
\end{aligned} \tag{1.7}
$$

And from eq. 1.2:

$$
\begin{aligned}
&F_{Jx} = 43N \\
&F_{Jy} = 50 + 25 = 75N
\end{aligned} \tag{1.8}
$$

The resultant of the joint reaction force can be calculated from eq. 1.1 again:

$$
F_J = \frac{F_{Jx}}{\cos\beta} = \frac{43}{\cos 60} = 86N \tag{1.9}
$$

So the joint reaction force is actually quite a bit greater than the force the muscle needs to generate to balance the head in this forward position. The job of the smaller muscles, such as the rotatores, multifidi, and the suboccipital muscles, and the important stabilizing effects of the spinal ligaments and joint capsules serve to counterbalance the shearing effects within and across joints. The joint reaction force, for example, can be resolved into rectangular components, **Figure 3**. These tangential forces within the joints are the ones that stimulate the development of osteophytes and lead to a gradual development of intervertebral osteochondrosis or disc disease. And remember, the forces calculated here are merely those induced by balancing the head against gravity.

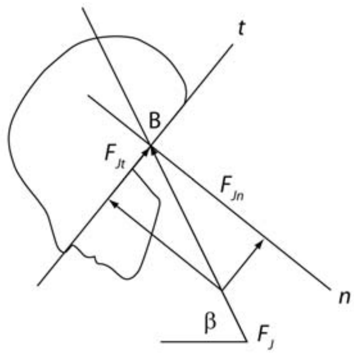

Figure 3. The joint reaction force broken down into rectangular components. The tangent t is drawn as an approximation of the joint line. The normal force n is 90 degrees to the tangent. (Adapted from Ozkaya N, Nordin M: *Fundamentals of Biomechanics*, 2nd edition, New York, Springer, 1999.)

Actually, there is still one major problem with this idealized model. It disregards the load bearing capacities of the other joints in the neck. It is an approximation and a simplification of a complex system. Our model could be infinitely more complex if we considered all of the joints, all of their degrees of freedom, all of the lines of action of the various muscles involved, as well as their relative power. In automotive engineering, these biomechanical simplifications are common, and many are used today in our Federal Motor Vehicle Safety System regulations.