

Passage 4

From Football Physics by Timothy Gay

The first, most basic instruction coaches give players about tackling an opponent goes something like this: "Keep your feet apart, stay low with your head up, and drive upward and through the opposing player." In order to understand why this technique is so effective, we now take up two new physics ideas: the center of mass and torque.

Let's consider torque first. Simply put, torque is the rotational equivalent of force. In the same way that force causes a mass to accelerate along a straight line, torque causes objects to rotate about a pivot line, sometimes called the axis of rotation. The bigger the torque, the more effective it is at causing the object to which it is applied to rotate about its pivot line.

We can illustrate these concepts by considering the simple act of opening a door. The door rotates about its pivot line, defined by its hinges. Let's now apply a force of, say, five pounds to the door, with the direction of the force being perpendicular to the plane of the door. If the door is three feet wide, and we apply the force at its edge farthest away from the hinges, the lever arm of this force is three feet. The torque we apply to the door is three feet \times five pounds = fifteen pounds-force feet (lbf \times ft). Alternatively, we can apply the same perpendicular force to the door, but now at a distance of 0.1 foot from the hinges. Now the lever arm is 0.1 foot, and the applied torque is 0.5 lbf \times ft. Which torque is more effective in opening the door? It doesn't take Tom Landry to figure this one out—it's the first one. The value of applied torque is simply a quantitative measure of how effectively the force we're applying opens the door.

Now consider a different possibility. We'll apply five pounds of force to the door as before, and we'll apply it to the edge of the door farthest from the hinges, just as before.

But now we change the direction of the applied force so that it points directly through the pivot line, parallel to the plane of the door. Common sense tells us that now the force we've applied isn't at all effective at opening the door. How does this relate to the torque? The lever arm of the force is now zero, because the force direction extends through the hinges themselves. Thus, the torque is zero; that door isn't going anywhere.

Torque by itself doesn't tell us much about tackling unless we combine it with an understanding of a player's center of mass. An object's center of mass is essentially the point through which we consider the pull of gravity on that object to act. This is why the center of mass is also referred to as the center of gravity. Most people have a basic concept of where the center of mass of an object lies—roughly at the object's center. And most people know that the admonishment "Keep your center of mass low!" means, roughly translated, "Crouch down, you!" This isn't wrong, but in order to really understand the center of mass, we need to determine the "center" of an object a little more carefully.

A player's center of mass is roughly just below his rib cage, on his vertical center line. When a player assumes a wide stance and crouches down to make a hit, his center of mass lowers (but remains in his torso area). If we constructed his helmet of lead, the center-of-mass point would move up perhaps an inch, because his head area would now be heavier. If we put the same amount of lead in his shoes (and how many of us haven't seen linemen who seemed to have this problem?), his center of mass would move down a few inches.

Here's the bottom line. When tackling or blocking, the reason to stay low and drive upward through the opposing player is so that you can control his motion by exerting far more torque on him than he does on you. Newton's Third Law still holds. You exert the same force on him as he does on you, but by using your knowledge of the centers of mass, you can completely dominate him in terms of torque.

Questions

Question 1: The scientific term *torque* means

- A. a quantitative measure
- B. the axis of rotation
- C. a rotational force
- D. the pivot line

Question 2: To illustrate the effects of torque, the author uses the example of

- A. closing a door
- B. making a tackle
- C. accelerating along a straight line
- D. opening a door

Question 3: The mathematical units used in the passage to measure torque are

- A. force pounds per foot
- B. pounds–force feet
- C. feet
- D. pounds

Question 4: To really understand tackling, a football player should grasp not only torque but also

- A. center of mass
- B. the pull of gravity
- C. how to crouch
- D. the importance of acceleration

Question 5: A player can lower his center of mass by

- A. taking harder courses
- B. assuming a wide stance

- C. adjusting his shoulder pads
- D. replacing his helmet

Question 6: The author makes a joke about filling helmets and football shoes with lead to illustrate which point?

- A. we need to be careful when determining the center of an object
- B. to find the center of mass, look along the vertical center line
- C. that a player's center of mass is just below his rib cage
- D. that the center of mass can be raised or lowered

Question 7: A player who applies proper physics can block or tackle successfully by

- A. applying the same amount of force as his opponent
- B. by using his torque to overcome the other player
- C. staying low
- D. applying Newton's Third Law

Question 8: The author uses a mathematical formula (distance times force) to

- A. give his argument scientific validity
- B. deliberately confuse the student
- C. satisfy sports fans who love statistics
- D. determine whether football coaches are right

Question 9: The author implies that some linemen are slow. He does this by saying that

- A. some linemen have a high center of mass
- B. some linemen have lead in their shoes
- C. football coaches have to keep yelling at their players
- D. linemen in a crouch can't run very fast

Question 10: Taking the passage as a whole, the author thinks the football coach's advice in the first sentence is

- A. correct
- B. false
- C. misguided
- D. missing the point

Answers

1. C 2. D 3. A 4. A 5. B 6. D 7. B 8. A 9. B 10. A

Commentary

In Question 1, you need to recognize that "rotation" is the key word in a definition of torque. That cuts the possible answers down to B and C. C is correct because torque is a way to describe "force." The author develops the example of opening a door throughout paragraphs three and four, so you shouldn't have trouble recognizing that in Question 2. Question 3 will probably send you back to the passage where you could check your memory of the mathematical units. Question 4 is answered in the first paragraph and repeated at the beginning of the fifth paragraph, and repeated one final time in the last paragraph. Applying a little common sense and reflecting on what the author has indicated about center of mass should help you solve Question 5.

In Question 6, all the answers are correct, but D is the most relevant to the author's purpose. The answer to Question 7 can be found in the last paragraph. Questions 8 and 10 refer to the overall point of the passage—do football coaches give good advice about tackling? Question 9 requires you to notice how the tone of the passage shifts—largely signaled by the presence of parentheses—when the author makes a small joke.