

Physics of the Human Body, 2nd Edition

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New Insights, Updates, and Questions

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Ch. 1. Terminology, the Standard Human, and Scaling

“Recent” Epiphanies on Who We Are

The physics of the human body arises from the biology of the human body. Insights on macroscopic, functional physiology can be gleaned from human evolutionary biologists/anthropologists. (Others focus on chemical/biological details.) In the big picture: ***Why we are what we are?*** In 1973, Theodosius Dobzhansky noted “Nothing in Biology Makes Sense Except in the Light of Evolution” in his so-named essay.

As Daniel Lieberman has noted: “We evolved to eat different diets, to run differently, and live differently from the ways we do today. People are looking to evolution to find out how our bodies adapted and what might be healthier for us. That’s good.”

(“Nothing in Biology Makes Sense Except in the Light of Evolution” (Theodosius Dobzhansky, *The American Biology Teacher* (1973) 35 (3): 125–129. <https://doi.org/10.2307/4444260>.)

(<https://www.harvardmagazine.com/2011/08/run-barefoot-says-daniel-lieberman>, which cites the *New York Times*, <https://www.nytimes.com/2011/08/23/science/23conversation.html>)

(*The Story of the Human Body: Evolution, Health, and Disease* by Daniel Lieberman)

Ch. 2. Statics in the Body (Section 2.3.4, Vertebral Column; Section 3.2.1, Stability; Figure 3.8; Appendix F, Pregnancy)

How do Male and Female Skeletons Differ?

It has been known for some time that male and female skeletons differ in several ways: in size (of course), in the hips, the brows, and so on, but only relatively recently has it been observed that the shapes of their lumbar vertebrae differ. The lowest two in males, L4 and L5, are dorsally wedged, meaning that they are wedges with the part in back thinner than that in the front, while the others L3 and so on are not wedged. Females have three dorsally wedged vertebrae: L3, L4 and L5. (see below) Why? As noted by Dobzhansky “Nothing in Biology Makes Sense Except in the Light of Evolution.” The dorsal wedge in the third vertebra in women produces a curvature in their spinal cords that probably helps them maintain stability with the extra loads they have in front of (anterior to) their hips during pregnancy while standing, and this probably evolved as an evolutionary need or preference.

(K.K. Whitcome, L.J. Shapiro, D.E. Lieberman: Fetal load and the evolution of lumbar lordosis in bipedal hominins. *Nature*. 450, 1075-1078 (2007), with correction: Corrigendum: Fetal load and the evolution of lumbar lordosis in bipedal hominins Katherine K. Whitcome, Liza J.

Shapiro & Daniel E. Lieberman *Nature* 450, 1075–1078 (2007); doi:10.1038/nature06342)

(Theodosius Dobzhansky, *The American Biology Teacher* (1973) 35 (3): 125–129.

<https://doi.org/10.2307/4444260>).

Ch 3. Motion (Section 3.4, Running)

Is There a Smarter Way to Run?

When you run with the usual heel-down to toe-off step you experience less shock upon initial foot impact when you wear running shoes than when you are barefoot. This is not surprising. However, after impact there still a shockwave that travels up your leg and eventually hits your head. But it is surprising that you experience much less shock if you run barefoot when the front of your foot (the ball) makes contact rather than your heel (whether shod or barefoot, and whether you run this way on a hard or soft surface). This is how our bodies evolve (D.E. Lieberman, M. Venkadesan, W.A. Werbel, A.I. Daoud, S. D'Andrea, I.S. Davis, R.O. Mang'Eni, Y. Pitsiladis: Foot strike patterns and collision forces in habitually barefoot versus shod runners. Nature 463, 531-535 (2010))

(<https://www.harvardmagazine.com/2011/08/run-barefoot-says-daniel-lieberman>, which cites the New York Times, <https://www.nytimes.com/2011/08/23/science/23conversation.html>)

Ch 3. Motion (Section 3.4, Running)

How fast do you naturally run?

When you intend to run a few miles, it seems your body rhythms default to a pace that burns the fewest calories per unit distance-which is the pace you are most comfortable with, rather than, as long believed, to a pace that minimizes calories over the whole distance, independent of pace. Of course, you can increase your pace by will, listening to music with a pace faster than your natural rhythm, or running with a runner with a faster natural pace

([https://www.cell.com/current-biology/fulltext/S0960-9822\(22\)00563-2](https://www.cell.com/current-biology/fulltext/S0960-9822(22)00563-2),

<https://www.wsj.com/articles/running-faster-means-overriding-your-ancestors-caloric-frugality-11651166037>)

Ch 3. Motion (Section 3.4, Running)

How should running shoes be chosen to minimize injury during running?

This will continue to be a question It has long been thought it best to minimize injury running shoes should be chosen to control impact forces or pronation. One relatively recent study has concluded that after hundreds of studies, it is best to choose them for comfort.

(B.M. Nigg et al., Br. J. Sports Med. (2015) doi:10.1136/bjsports-2015-095054)

Ch. 3. Motion (Section 3.4, Running; Appendix F.4)

Why do you run slower as you age (during adulthood)?

This due to fewer strides per unit time or shorter stride lengths. Of course, both contribute, but the dominant reason why you run slower because your stride is shorter. This makes sense due to weakened ankle muscles.

(P. de Vita et al., Med. Sci. Sports Exerc. (2015) doi:10.1249/MSS.0000000000000744)

Ch 3. Motion (Section 3.12, Flight of the Ball)

Are pitched baseballs stickier, spinning faster, and “moving” more?

The coefficient C_L in the Magnus force (lift) law appears to be proportional to the ball rotation rate, and this translates into about 0.43 inches of movement by the time a baseball ball reaches home plate for each additional 100 rpm of spin on a fastball. Measurements by Major League Baseball (since 2015) have shown that the average spin rate of a four-seam fastball rose from 2238 rpm in 2015 to 2307 rpm in 2020. The spin rates for some pitchers increased by 300 rpm or more, which means their fastball “rose” (i.e., dropped less) by over an inch more and the motion on their curveballs (such as an additional drop) increased by the same amount. Some think these increased spin rates were due to more prevalent “foreign” substances on the pitchers’ fingers. Such sticky substances help the ball maintain rolling contact on the fingers for a longer time before release. (<https://physicstoday.scitation.org/doi/10.1063/PT.6.1.20210708a/full/>)

Ch 6. Metabolism (Section 6.4, Metabolic Rates)

Update: How has our understanding of metabolic rates and aging changed recently?

Chapter 6 presented then current data on daily metabolic rates under basal conditions and how these rates change with activity. The basal rate accounted for only ~50-70% of the total energy expenditure (and activity level of ~1.4-2.0). A recent comprehensive study examined the statistics of total energy expenditures (TEEs), and how it varies with fat free mass (FFM) and age. The TEE (MJ/day) followed the universal power law $TEE = 0.677 FFM^{0.708}$ with FFM in kg for all, with different age groups falling over or below the adult ranges. It increases rapidly from 0-1 yr to ~46% above adult values and then declines to adult levels from 1-20 yr (and so are above this curve), remains stable during adulthood (20-60 yr), and then declines by about 0.7% per year for each year past 60 years; these are due to changes in the metabolic rate of tissues and the variations in physical activity with age. Similar trends are seen for the basal energy expenditures (BEE). The TEE are generally above the values given by this relation for men and below it for women. The TEE varies among people by more than $\pm 20\%$ even when controlling for fat free mass, fat mass, sex, and age. In terms of total body mass (TBM, in kg), $TEE = 0.807 TBM^{0.593}$.

(<https://www.science.org/doi/10.1126/science.abe5017>, main article with the Supplemental Materials are at <https://hal.archives-ouvertes.fr/hal-03364046/document>)
(<https://nypost.com/2021/08/13/metabolism-doesnt-slow-down-in-middle-age-shocking-study>)

Ch. 6. Metabolism (Section 6.4, Metabolic Rates)

Why do women often feel cold in office buildings, as they are designed?

This is because office buildings have usually been designed for the higher metabolic rates of males, and their comfort.

(B. Kingma, et al., Nature Climate Change (2015) doi:10.1038/nclimate2741)

Ch 6. Metabolism (Section 6.4, Metabolic Rates)

Is the BMI metric still in vogue?

As noted in Chapter 6, your body-mass-index (BMI), mass (in kg) divided by height (m), is often used to classify you as overweight ($30.0 > BMI > 25.0 \text{ kg/m}^2$) or obese ($> 30.0 \text{ kg/m}^2$) from a medical viewpoint. The (U.K.) National Institute for Health and Care Excellence (NICE) claims another metric, the waist-to-height ratio, is a better metric. Ratios between 0.40-0.49, and

moreover all waists less than half your height, seem to indicate you are fine, while ratios of 0.50-0.59 would put you at higher risk for type 2 diabetes, high blood pressure, and heart disease, even if your BMI is between 30 and 35 kg/m² (Class I obesity) or smaller. The new metric seems to be better for assessing your health because it better accounts for body fat in your middle, which is visceral fat that is linked to your organs and blood vessel, rather than bottom and thigh fat, which is subcutaneous, and so associated with the skin and not body organs. Visceral fats are more detrimental to your health. This metric seems to work for all body types.

(<https://www.nice.org.uk/news/article/keep-the-size-of-your-waist-to-less-than-half-of-your-height-updated-nice-draft-guideline-recommends#:~:>,
<https://www.dailymail.co.uk/femail/article-10723377>, <https://www.cdc.gov/obesity/basics/adult-defining.html#:~:text=Class%20I%20BMI%20of%2030,categorized%20as%20%E2%80%9Csevere%E2%80%9D%20obesity.>)

Ch. 10. Sound, Speech, and Hearing (Section 10.2, Speech Production)

Why do we easily recognize human screams?

Human screams have a very distinctive frequency profile in the 30-150 Hz range. They are easily recognizable because they do not overlap other common audio patterns (and this is likely due to evolution---the need to survive).

(L. H. Arnal et al., *Current Biology* 25, 1--6 (2015))