Al-Mustaqbal University

College of Technology and Health Sciences

Medical physics Department

Medical Physics

First Semester

3rd stage

Lesson 4

Forces on and in the body

Part 2

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Dynamic

Let's consider a body is moving in one direction with constant acceleration or deceleration (a). The newton second law is;

$$F = ma$$

Where m; is the body mass and a; is the acceleration.

The acceleration of any body is the change in its velocity during time interval. So;

$$F = \frac{m\Delta v}{\Delta t}$$

$$or; \quad F = \frac{\Delta(mv)}{\Delta t}$$

That means the force equals the change in the momentum over time, where the term *(mv)* is called the momentum.

Example:

A 60 kg person walking at 1 m/sec bumps into a wall and stopes in a distance of 2.5 cm in about 0.05 sec. What is the force developed on impact?

$$\Delta(mv) = (60 \times 1) - (60 \times 0) = 60kg.\frac{m}{sec}$$

$$F = \frac{\Delta(mv)}{\Delta t} = \frac{60}{0.05} = 1200\ kg.\frac{m}{sec^2} = \ (1200\ N)$$

Dynamic force in the body.

When the heart beats (systole), about 60 g (0.06 kg) of blood is given a velocity of about 1m/sec in about 0.1 sec.

Then the upward momentum is;

$$mv = 0.06\,kg \times 1m/\sec = 0.06\,kgm/sec$$

$$mv = 0.06\,kgm/sec$$

Thus; the force produced will be

$$F = \frac{\Delta(mv)}{\Delta t} = \frac{0.06}{0.1} = 0.6\,N$$

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This force generate a downward force in the rest of the body (reaction force according to Newton third law) equals to the upward force.

Thus; the dynamic force in the body generate an increase of weight when heart beats.

Dynamic force on the body.

- ***Jumping***

If a person jumps from a height of 1 m and lands stiff-legged. The body is traveling at 4.5 m/s just prior to hitting, and if the padding collapses by 1 cm, the body stops in about 0.005 sec.

$$F = \frac{\Delta(mv)}{\Delta t}$$

If the final speed is zero as the body stopped;

$$F = \frac{m \times 4.5}{0.005}$$

$$F = 900 \times m$$

Now if we consider the mass of this person is 70 kg.

$F = 900 \times 70 = 63000\ N$ (~6400kg) (~100times the person weight)

If this person landed on a gym mat the deceleration time would be longer, and if followed the normal body reaction he would land toes first and bend his knees to decelerate over a much longer time, thus decreasing the landing force (figure 1)

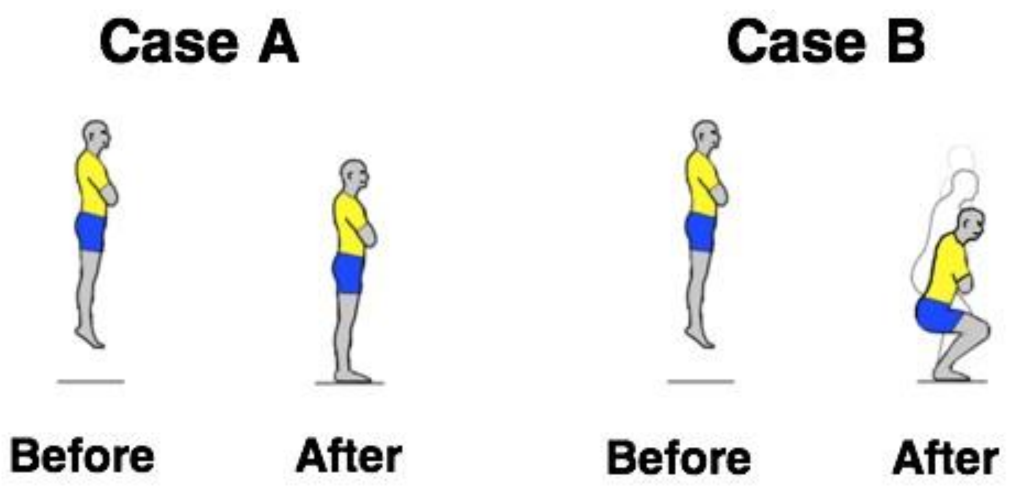

Figure 1. Increasing the landing time to reduce forces

- **Car accident**

A passenger in a car has higher momentum than walking because of the higher speed. In the accident, the car stopes in a very short time, producing a very large forces. These forces result in broken bones, injuries and sometimes death (figure 2).

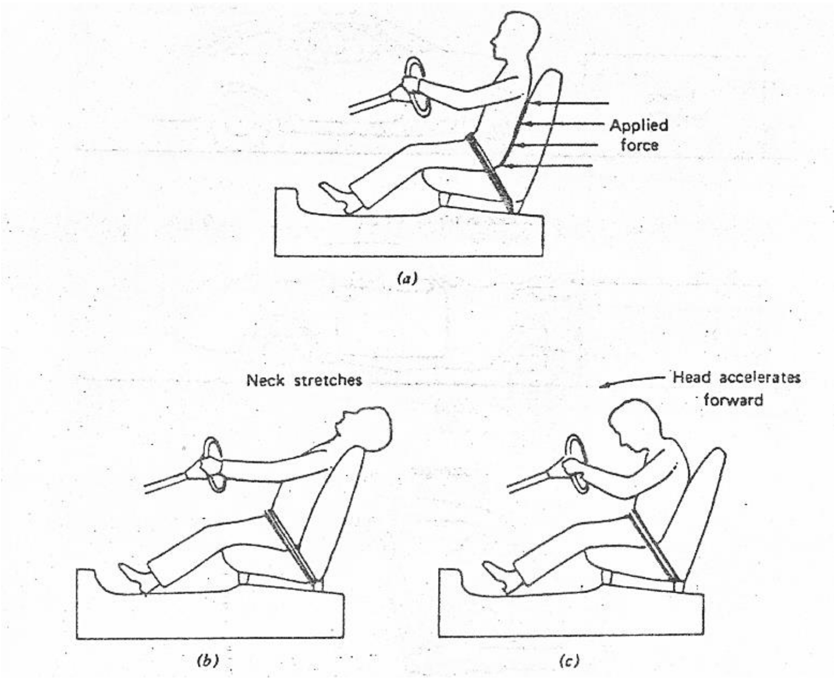

Figure 2. Car accident

1. When car is struck, forces act through seat forcing the trunk of the body to move forward (image a).
2. The inertia of the head causes it to stay in place leading to severe stretching of the neck (image b).
3. In millisecond the head is forced to accelerate forward (image c).
4. Head could be hitting the steering wheel.
5. Neck could be suffering from severe injuries.

To reduce the risk many safety options have been added to modern cars such as seat belts, air bags, and rubber steering wheel.

- **High acceleration motion**

High acceleration motion such as space craft, some aircraft and some fast cars can produce number of effect:

1. Increase or decrease in body weight
2. Changes in the hydrostatic pressure
3. Distortion of the elastic tissues of the body.
4. The separation of solids in the liquids.
5. Losing control because the body does not have proper muscles to work against large acceleration motion.
6. Under very high accelerations, the blood may pool in some regions in the body causing unconsciousness because the lack of blood flow to the brain.

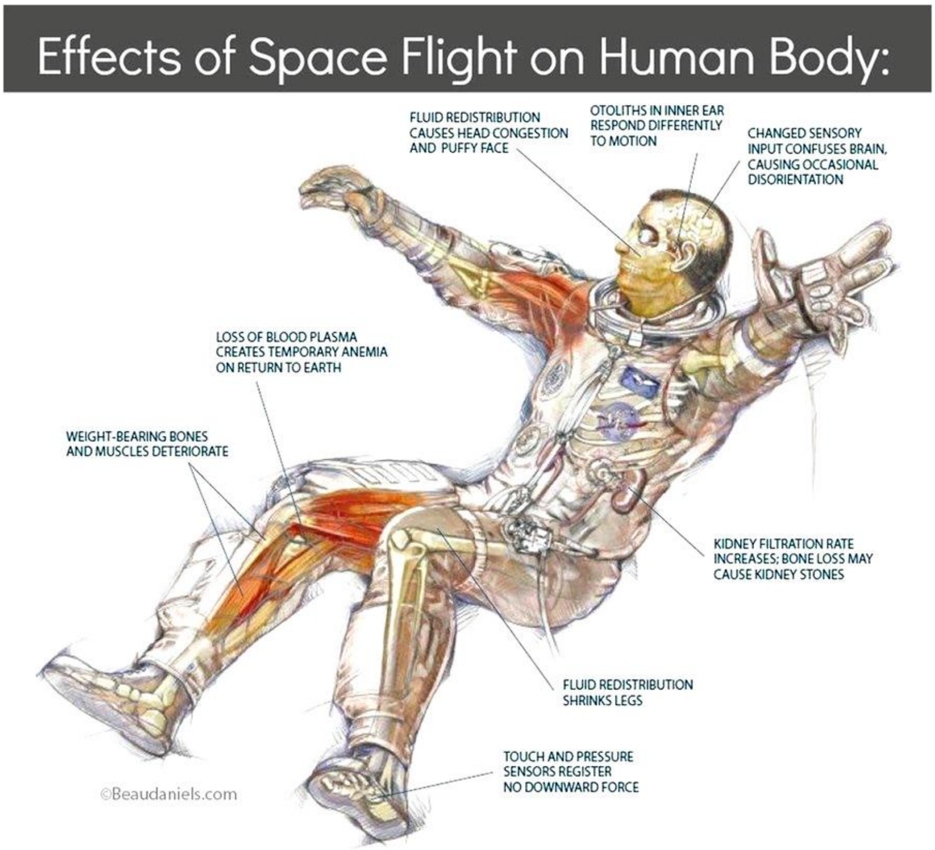

Figure 3. The effect of acceleration

- **Oscillatory motion**

If we subject the body to oscillatory motion, resonance behavior can occur. Each of our organs has its own resonant frequency depending on its mass and the elastic forces that act on it. If it is vibrated at its resonant frequency, pain or discomfort occurs.

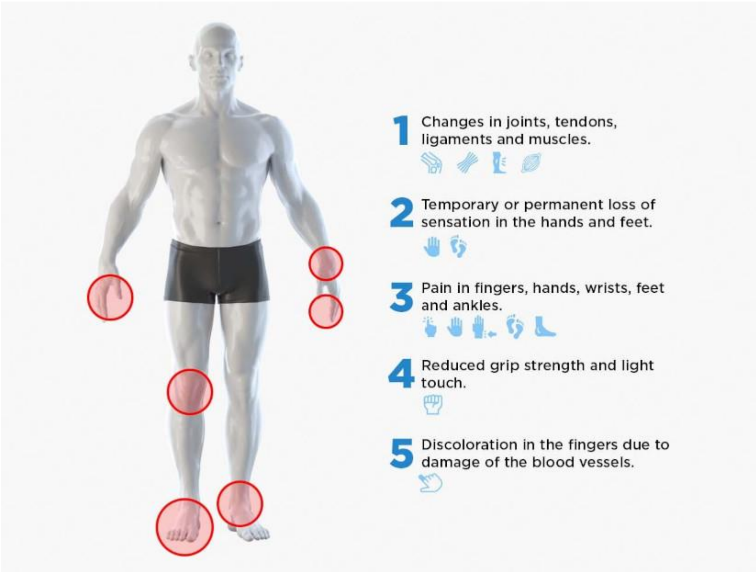

Figure 4. Some effect of vibrations

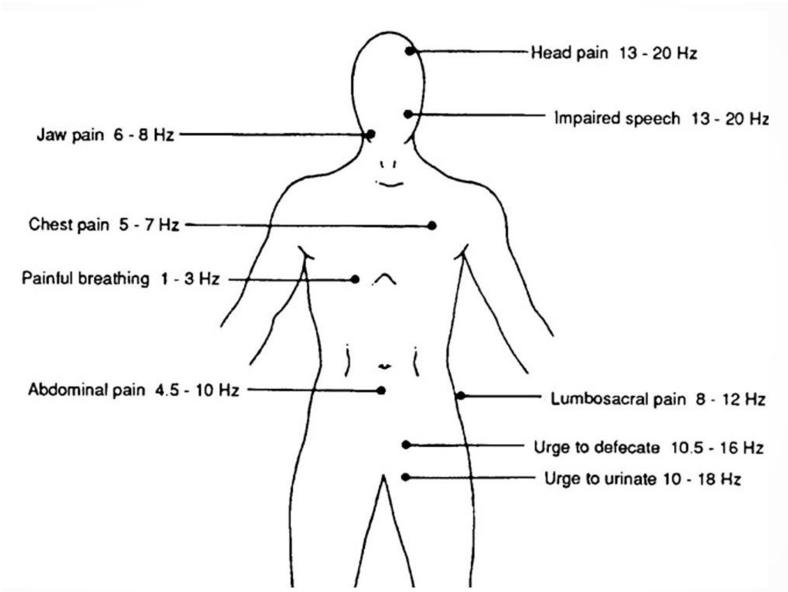

Figure 5. Various sensations observed by humans subjected to vibrations of different frequencies

Exercises

1 **The Newton's second law could be written as**

(a) F = Δ(v)/ Δt

(b) F = Δ(a)/ Δt

(c) F = Δ(ma)/ Δv

(d) F = Δ(mt)/ Δv

(e) F = Δ(mv)/ Δt

2 **A 60 kg person walking at 1 m/sec bumps into a wall and stopes in a distance of 2.5 cm in about 0.05 sec. What is the force developed on impact?**

(a) 1200 N

(b) 12000 N

(c) 2100 N

(d) 12 N

(e) 0 N

3 **If a person jumps from a height of 1 m and lands stiff-legged, the force generated almost;**

(a) 2 times the body weight

(b) 50 times the body weight

(c) 100 times the body weight

(d) 1000 times the body weight

(e) No force generated

4 **Under very high accelerations, the blood may pool in some regions in the body causing unconsciousness because**

(a) Lack of blood flow to brain

(b) blind eyes

(c) high wind

(d) Lack of oxygen

(e) None of them

5 **When humans subjected to vibrations of different frequencies, headache occur at**

(a) 2-6 Hz

(b) 8-12 Hz

(c) 10-18 Hz

(d) 13-20 Hz

(e) 20-40 Hz