

Lesson 9 Human movement in a fluid medium – effects of fluid force on human motion

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This lesson contains 10 screens teaching text, 2 zoomable figures and 6 videos. This lesson requires approximately 2 - 4 hours of study but can vary depending on the student.

Hydrotherapy is the application of water for the treatment of physical or psychological dysfunction. Hydrotherapy is a natural treatment form of physical treatment, which is also called as water therapy, aquatic therapy, and balneotherapy. Use of water in various forms and in various temperatures can produce different effects on different system of the body (3).

Hydrotherapy works by using the specific properties of water to aid in rehabilitation. The physiotherapist has to know the biomechanical characteristic of the water as a fluid medium in order to achieve the best therapeutically effect during aquatic therapy.

Character of the fluid medium

Fluid substances

Fluids are a phase of matter liquids, gases and plasmas. From a physics aspect, a fluid is a substance that continually deforms (flows) under applied shear stress or external force. Every type of fluids have similar mechanical behaviors. Water and air are fluids which exert forces on the human musculoskeletal system (1).

There are several factor which affect the influence of the fluid on a body.

1. Relative velocity
2. Flowing
3. Properties of the fluid

Relative velocity of the body which moves through a fluid medium means the velocity of a body with respect to the surrounding fluid. The relative velocity influences the magnitude of the acting forces.



When an object or the human body moves in any fluid medium (e.g. air, water) there is less or more disturbance in the fluid. The type of the generated flow depends on the object's velocity relative to the fluid medium. There are two distinct categories of fluid flowing.

Laminar flow is generated when the body moves with low velocity relative to the fluid medium. In laminar flows fluid layers slide in parallel, smoothly or in regular paths (Fig.1).

Turbulent flow is generate when the body moves with high velocity relative to the fluid medium. In turbulent flow the fluid does not flow in parallel layers but undergoes irregular fluctuations and mixing, and there is a disruption between the layers. Common examples of turbulent flow are blood flow in arteries, atmosphere and ocean currents (Fig.1).

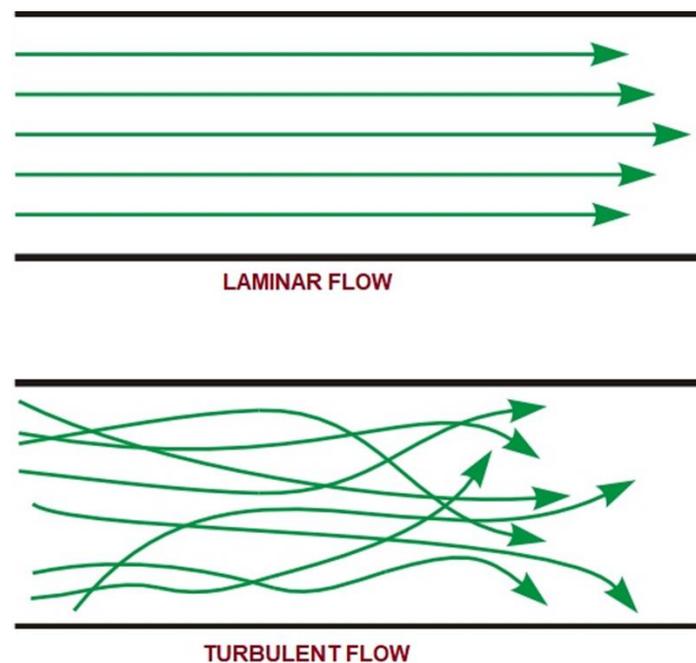


Fig. 1 The laminar and turbulent flow of fluid medium

A fluid medium has many distinctive properties which cause different biomechanical behavior and effect.

Let's see the specific characteristics of the fluid medium.

Properties of fluids

The biomechanical properties and behavior of a fluid determine the magnitude of the forces generated on a body which is immersed into a fluid medium. The basic physical properties are the following (1):

Density is the mass of the fluid per unit volume. It unit is kg per cubic meter.

Specific weight is the ratio of weight to volume.

The heavier and denser the fluid surrounding an object, the greater the magnitude of the forces the fluid exert on the object.

Viscosity is the property of fluid which defines the interaction between the moving particles of the fluid. It is the measure of resistance to the flow of fluids.

The greater the extent to which a fluid resists flow against an applied force, the more viscous the fluid is (1).

The biomechanical behavior of fluid medium

Buoyancy or buoyant force is an upward force exerted on an object that is wholly or partly immersed in a fluid.

Please now watch the following video about buoyant force:

<https://www.youtube.com/watch?v=2fCVMhCOGWE>

Archimedes' principle is the statement that the buoyant force on an object is equal to the weight of the fluid displaced by the object.

Please watch the following video about which demonstrates the Archimedes' principle:

<https://www.youtube.com/watch?v=vJ36urazDu4>

Flotation is the ability of a body to float in a fluid medium. The flotation depends on the relationship between the weight of the body and the buoyancy. As the Fig. 2 shows, when the buoyant force and the weight (gravitational force) are the only two forces which act on the body and the magnitude of these forces are equal, the body floats in the fluid medium (water) (1).

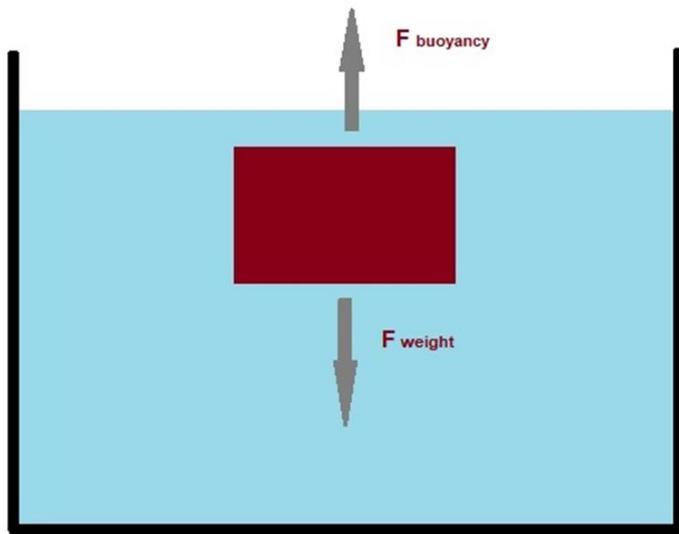


Fig. 2 Flotation occurs when the buoyancy force and the weight of the body are equal

Surface tension: The cohesive forces between liquid molecules are responsible for the phenomenon known as surface tension. The molecules on the surface of a liquid, that is, the interface between the liquid and the air are bound together by a weak force. This force makes the liquid form a layer and is caused due to the cohesive force between the molecules of the liquid.

Please watch the demonstration of the surface tension by the following video:

<https://www.youtube.com/watch?v=hzYkzR7YDqs>

Drag is a force acting opposite to the relative motion of any object moving with respect to a surrounding fluid. This can exist between two fluid layers or a fluid surface and a body's surface immersed in the fluid. Therefore, a drag is resistance force which slows the motion of a body moving in a fluid medium such the water. Drag depends on the properties of the fluid and on the size, shape, and speed of the body.

The resistance provided by the drag of the water, as a fluid medium, is usable in the physiotherapy in order to strengthen muscles. Moreover, this property of the water helps to maintain the immersed body in a relatively stable position. Due to this fact, the water is a safety medium for those people who are at risk of falls.

Hydrostatic pressure refers to the pressure that any fluid in a confined space exerts. The amount of pressure inside a body of fluids increases with its depth. The hydrostatic pressure create pressure on the immersed body from all directions.

Please watch the demonstration of the hydrostatic pressure by the following video:

Physiological effects of water on the human body

The effect of the water temperature on the immersed body

The immersion of the human body in water causes reactions in bodily functions. Water temperature, in particular, is a primary factor affecting and altering body functions.

During immersion, the temperature of the water affects the function of the cardiovascular and respiratory system. Cold water exerts a stimulating effect and activates the sympathetic nervous system and endocrine function. It stimulates the cold receptors, resulting in the appearance of vasoconstriction. High water temperatures, conversely, cause the stimulation of heat receptors, resulting in pronounced vasodilation and overheating of the body (5).

The higher temperature of water exerts a relaxing effect and decreases the tone of the vascular muscles with the consequence of an increase in blood flow. Hyperemia, which is the increase of blood in an organ or tissue, as a result of the tissue vasodilation, produces analgesic and anti-inflammatory effect. Increasing muscle temperature decreases stiffness and increases the flexibility of the muscles (4).

According to the Aquatic Exercise Association 2008 Standards and Guidelines water varying from 28-30 degrees Celsius is the most comfortable temperature for typical water fitness classes.

The effect of the buoyancy on the immersed body

As you remember, buoyant force is an upward force by the fluid applied on a body immersed in it. During aquatic immersion, a considerably relative reduction of weight is experienced due to the buoyancy forces acting on the body. As a result, the load on articulations of the lower limb and spine is considerably reduced. For this reason, the physical activity on water is recommended for people with degenerative articulation problems (2).

The upward buoyant force of the water helps to reduce stress in the postural muscle due to flotation, therefore the immersion in water is a useful method for relaxation.

The effect of the drag on the immersed body

Drag force resists the movement of the human body in water, therefore muscle strength increases with exercises against drag forces. Another biomechanically significant factors of the water in respect of muscle strengthening are the turbulent flow and buoyancy (if the direction of the motion is opposite to the direction of the buoyancy force).

The effect of the hydrostatic pressure on the immersed body

One of the effects of hydrostatic pressure on the body is that lung volume and vital capacity decrease significantly with aquatic immersion. When immersed to neck level, the compression of the thoracic and abdominal cavity due to hydrostatic pressure causes an increase in the height of the diaphragm and reduces the circumference of the rib cage. So, the hydrostatic pressure applies constant resistance during breathing and can increase the inspiratory muscle strength. Moreover, it increases lung capacity and helps to release more air during exhale.

Due to the compressive effect of the hydrostatic pressure the venous and lymphatic flow increases, therefore hydrostatic pressure reduces swelling. (Human body flotation and organic responses to water immersion (2)).

Please watch the following videos which demonstrate some examples of the aquatic therapy:

https://www.youtube.com/watch?v=lcw_sE-ZcAs

<https://www.youtube.com/watch?v=UNfbTthda2E>

Study questions:

TRUE/FALSE questions

Read each statement below carefully. Choose T if you think a statement is TRUE. Choose F if you think the statement is FALSE.

1. Due to the compressive effect of the hydrostatic pressure the venous and lymphatic flow decreases.
T or F
2. The drag of the water is effective for unloading of joints.
T or F
3. Cold water activates the sympathetic nervous system and endocrine function.
T or F
4. The flotation of a body depends on the relationship between the motion of the body and the buoyancy.
T or F
5. The higher temperature of water increases stiffness and the decreases flexibility of the muscles.
T or F

Matching questions

In this exercise, you have to match each word with a definition.

1. Buoyancy
2. Flotation
3. Drag
4. Archimedes' principle
5. Fluid substances

- A. Fluid is a substance that continually flows under applied shear stress or external force.
- B. It is the ability of a body to float in a fluid medium.
- C. It is the statement that the buoyant force on an object is equal to the weight of the fluid displaced by the object.
- D. Buoyant force is an upward force exerted on an object that is wholly or partly immersed in a fluid.
- E. It is a force acting opposite to the relative motion of any object moving with respect to a surrounding fluid

References

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2. Llana-Belloch S, Lucas-Cuevas AG, Pérez-Soriano P, Priego Quesada JI (2013): Human body flotation and organic responses to water immersion. *Journal of Physical Education and Sport* 13:354 – 361
3. Mooventhan A and Nivethitha L (2014): Scientific Evidence-Based Effects of Hydrotherapy on Various Systems of the Body. *N Am J Med Sci.* 6(5): 199–209. doi: 10.4103/1947-2714.132935
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