# Application Paper for the Immune System

## Study overview and application


# The importance of a Healthy Body Composition for the Immune System

Find out how you can use body composition analysis to evaluate the immune system and take individual measures for your customers/patients.

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# Content

# The Human Body Composition

## Weight alone doesn't say much!

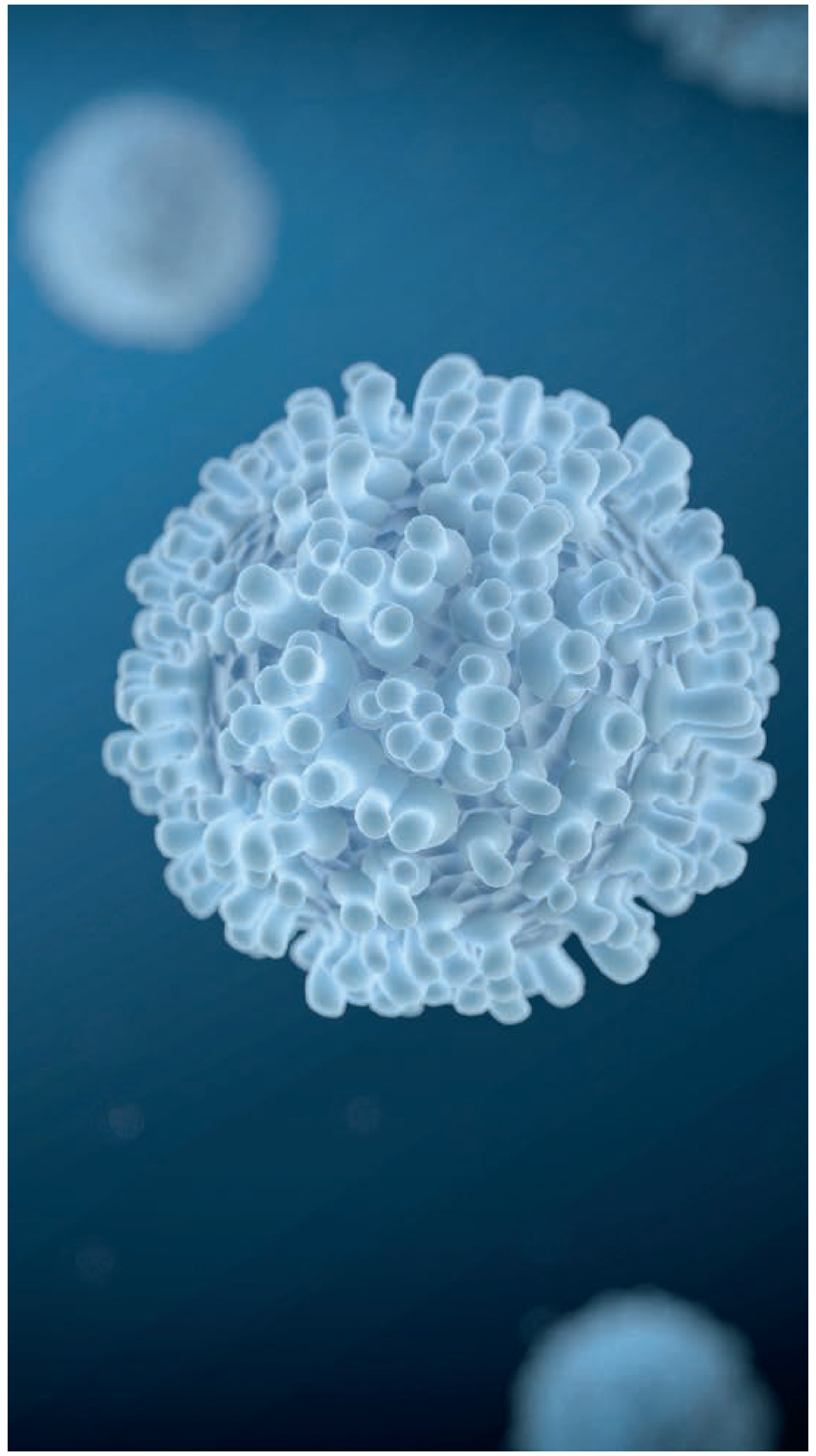
Examining the human body in its individual structures is an effective way to identify individual risks and deficits and to actively work on a stronger immune system through appropriate measures. Various models are known from anthropology to divide the structure of the human body. The model of the body compartments helps here. These body compartments represent the various tissues and fluids in the human body.

The **one-compartment model** considers the body as a whole and therefore only deals with the total body weight. It is not possible to make a qualitative statement about possible health risks using the one-compartment model, since it is not exactly clear what the total body mass consists of. In modern therapy and research, the **four-compartment model** is used as the basis for assessment.

### ▸ The one-compartment model


### ▸ The four-compartment model

## Healthy Cells



### An important factor for a strong immune system

In the bone marrow, our blood-forming system is created from the blood stem cells. Different cell types with various tasks and functions are formed from these stem cells. The large variety of white blood cells, the so-called leukocytes, make up a large part of our immune system.

### Lymphocytes

The most important group among the immune cells are the lymphocytes [1]. They form the basis for the acquired immune system and the immunological memory. One billion lymphocytes are constantly on the lookout for pathogens. Receptors on the cell surface allow the cells to recognize their targets. A lymphocyte can only recognize one specific antigen because it only has a large number of one specific receptor on the cell surface. Nevertheless, the body can effectively fight pathogens that have already occurred by storing a few copies of antigens. In the event that the pathogen reappears, the immune cells with the corresponding receptors are produced millions of times and the pathogen can be destroyed. You have a so-called "immunological memory" [2,3]. Lymphocytes include T-lymphocytes and B-lymphocytes, natural killer cells and their more specialized successor cells.

T-lymphocytes are responsible for the cellular immune response and mature in the thymus. The body's own cells, which are affected by viruses or mutations, are destroyed and antigens are attacked and destroyed directly.

1 Edward S. Gloub , The Cellular Basis of the Immune Response, 2nd Edition. Sinauer Associates, Inc. Sunderland, Massachusetts, USA (1981): 11-13
2 Crotty, S., & Ahmed, R. (2004, June). Immunological memory in humans. In Seminars in immunology. (Vol. 16, No. 3, pp. 197-203). Academic Press.
3 Crotty, Shane, et al. „Cutting edge: long-term B cell memory in humans after smallpox vaccination." The Journal of Immunology 171.10 (2003): 4969-4973.

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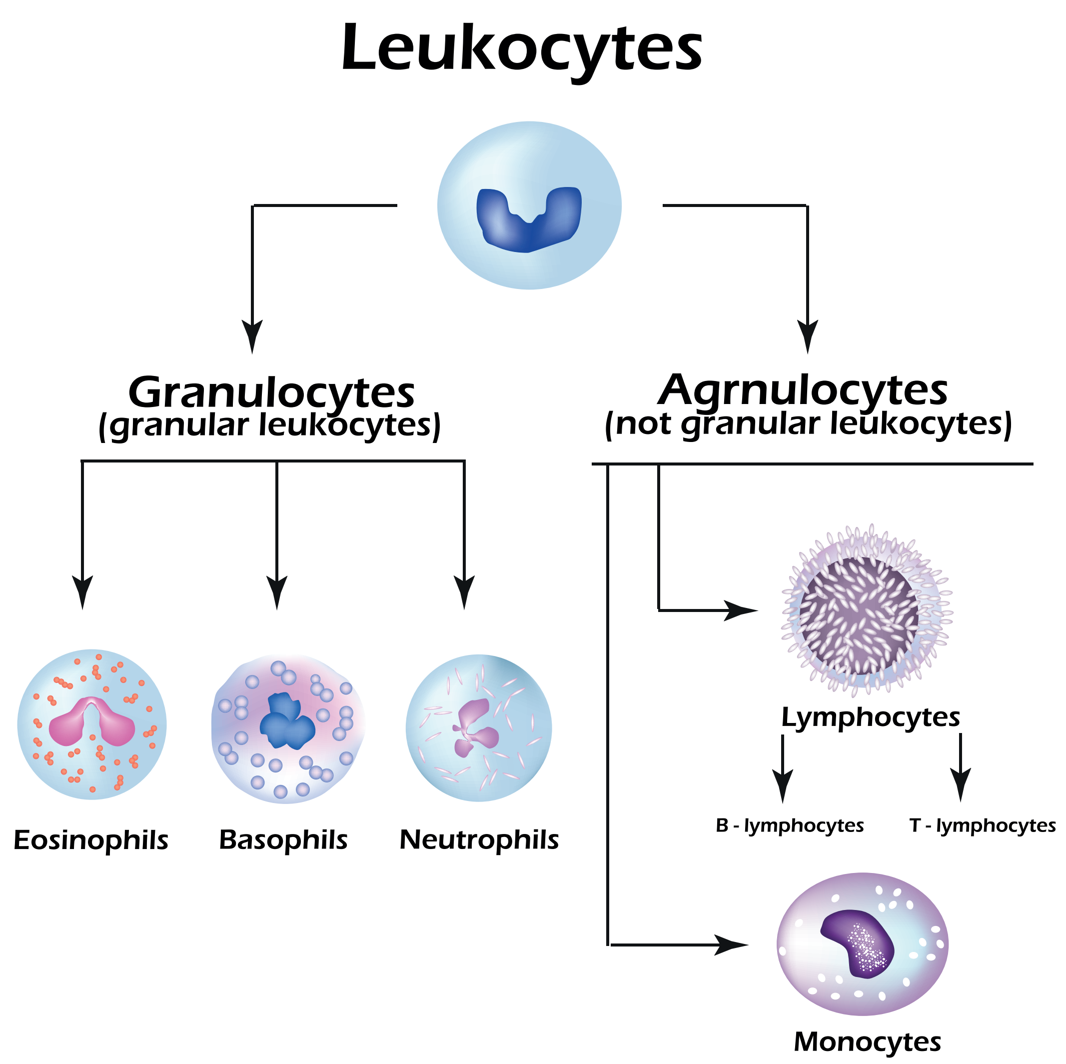
## Healthy Cells




Blymphocytes arise in the bone marrow and represent the humoral immune response. Large quantities of antibodies are produced with their successor cells, the plasma cells [4].

Natural killer cells belong to the innate immune system. They track down tumor cells or virus-infected cells and kill them.

Monocytes and macrophages belong to the group of phagocytes (phagocytes). They are largely responsible for the regulation of the immune response and emit a variety of chemical messengers to regulate the strength of the immune response. Monocytes move in the bloodstream and look for pathogens. They develop into macrophages as soon as they penetrate the tissue.

Granulocytes represent the largest group of leukocytes. The commonality between the different subgroups is that all granulocytes contain filled granules from different enzymes and bacteria-killing substances in their cells [5].

Dendritic cells can form both from monocytes and from precursor cells of T lymphocytes. They have a very specific structure and shape, which enables them to catch and digest pathogens and to present fragments of them on their surface for other immune cells. They are mainly present on surface fabrics, such as of the skin or throat, but can also to be found in large numbers in the inner mucous membranes.

### Humoral immune response:

The humoral immune response (from lat. [H] umor = moisture also juice, liquid) is the part of the body's immune response that is mediated by the non-cellular components of body fluids. Together with the cellular immune response, it forms the immune system of higher organisms [5].

4 Charles Janeway, Paul Travers, Mark Walport, Mark Shlomchik: Immunologie. 5. Auflage, Spektrum Akademischer Verlag, Heidelberg 2002
5 Webster's New World Medical Dictionary (3rd ed.). Houghton Mifflin Harcourt. p. 181.

# Muscle Mass - Strong Immune System

## What does the immune system have to do with muscles?

The study by Mariani et al. (1999) showed that senior adults with higher skeletal muscle mass had a higher number of immune cells in the blood, which indicates that muscles are related to the immune system [6]. In addition, muscle activation leads to the production of myokines in the muscle cells supporting a potential relationship between muscle activation an immune function [7]. Regular exercise of moderate intensity has been related to an increase of T lymphocytes, showing that this type of exercises can support and potentially improve immunity [8].

Basically, regular exercise has a positive influence on the body [8, 9] namely:

- strengthening the immune system
- the increase of skeletal muscle mass
- the reduction of body fat mass
- the increase of bone density

These effects of regular exercise reduce the risk of diseases such as diabetes II, obesity, different types of cancer and cardiovascular diseases [10]. In addition, it has been shown that older adults with low skeletal muscle mass are at greater risk of cardiovascular disease [11].

### Muscle function:

The musculature is an organ system that, together with the bones, joints, tendons and ligaments, forms the human support and musculoskeletal system. The skeletal muscles can be influenced arbitrarily by physical activity and act like a medicine for the body.

### What are myokines?

Myokines are hormone-like messenger substances that are released by the skeletal muscles through movement and contraction. The myokines train our immune system and protect us effectively against diseases.

6 Mariani, E. et al. (1999). Vitamin D, thyroid hormones and muscle mass influence natural killer (NK) innate immunity in healthy nonagenarians and centenarians.
7 Pedersen, B. K., & Febbraio, M. A. (2008). Muscle as an endocrine organ: focus on muscle-derived interleukin-6. Physiological reviews, 88(4), 1379-1406.
8 Simpson, R. J., Kunz, H., Agha, N., & Graff, R. (2015). Exercise and the regulation of immune functions. In Progress in molecular biology and translational science (Vol. 135, pp. 355-380). Academic Press.
9 Wayne, L. & Westcott, PhD. (2012). Resistance Training is Medicine: Effects of Strenght Training on Health.
10 Brandt, C., & Pedersen, B. K. (2010). The role of exercise-induced myokines in muscle homeostasis and the defense against chronic diseases. BioMed Research International, 2010.
11 Ricardo Aurelio Carvalho Sampaio et al. (2014) Arterial stiffness is associated with low skeletal muscle mass in Japanese community-dwelling older adults .

# How does Visceral Fat affect the Immune System

Visceral fat is a separate part of body composition analysis.

Current literature shows that visceral fat in particular, in contrast to subcutaneous fat, emits more inflammatory messengers and thus impairs the functions of the immune system [12]. In addition, other studies show that a high visceral fat percentage also increases the risk of numerous complications such as hypertension, cardiovascular diseases, diabetes II, obesity, glucose and fat metabolism disorders, fatty liver and the metabolic syndrome [12-18]. An accumulation of visceral fat leads to an increased production of adipokines [13]. These adipokines, in conjunction with the increased accumulation of macrophages, increase the inflammatory processes and the development of insulin resistance. This can result in an increased risk of complications and thus a weakened immune system [12, 17]. These complications are for example diabetes II, lipid metabolism disorders, fatty liver and high blood pressure [16]. Regular strength training and a balanced diet can reduce the visceral fat. This reduces the risk of harmful inflammatory reactions and improves the overall immune system [8, 20].

### Definition of visceral fat:

Our body fat is divided into subcutaneous fat (under the skin) and visceral fat (in the abdominal cavity). The visceral fat serves to protect the internal organs and as an energy reserve. However, increased storage of visceral fat poses health risks.

### Adipokine:

Adipokines are a group of endocrine-active proteins from adipose tissue, such as cytokines or peptide hormones. Adipokines have anti-inflammatory or pro-inflammatory properties and connect the metabolism with the immune system. With malnutrition, anti-inflammatory adipokines increase and pro-inflammatory decrease. With an increase of adipose tissue above normal metabolic status it works the other way around. [13]

12 de Heredia, F. P., Gómez-Martínez, S. & and Marcos, A. (2012). Chronic and degenerative diseases. Obesity, inflammation and the immune system. Proceedings of the Nutrition Society 71: 332–338.
13 P. Mancuso: The role of adipokines in chronic inflammation. In: ImmunoTargets and therapy. Band 5, 2016, S. 47–56.
14 Shafqat, M. N. & Haider, M. (2018). Subcutaneous to visceral fat ratio: a possible risk factor for metabolic syndrome and cardiovascular diseases. Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy 11: 129–130.
15 Barroso, T. A., Marins, L. B., Alves, R., Gonçalves, A. C. S., Barroso, S. G. & de Souza Rocha, G. (2017). Association of Central Obesity with The Incidence of Cardiovascular Diseases and Risk Factors. International Journal of Cardiova-scular Sciences 30 (5): 416-424.
16 Gruzdeva, O., Borodkina, D., Uchasova, E., Dyleva, Y. & Barbarash, O. (2018). Localization of fat depots and cardiovascular risk. Lipids in Health and Disease 17:218.
17 Janochovaa, K., Haluzika, M., Buzgab, M. (2019). Visceral fat and insulin resistance – what we know? Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub. 163 (1): 19-27.
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# Body Water

## A balanced body water for a strong immune system

In addition to the immune cells and other influencing factors, a balanced body water balance also plays an important role for the immune system [21]. Body water is responsible for the transport of numerous substances in the fluid compartments, which include the supply of cells with nutrients and the excretion of urinary substances [22].

Studies have shown that edema (water retention) and dehydration are very serious causes of the occurance and development of diseases [23].

If the fluid balance is not balanced, this may be due to an imbalance of the extracellular water in relation to the total body water. Edema occurs when the extracellular water is in a high ratio to the total body water. Dehydration occurs when the extracellular water has a low ratio to the total body water. Imbalances can either affect the whole body or only occur in isolated regions. Water retention can have various causes, such as congestive heart failure, kidney disease or liver diseases [24].

### Definition body water:

The body water describes the water contained in the body fluids. This is made up of intracellular and extracellular body water and serves as a solvent, building material, temperature regulator and means of transport.

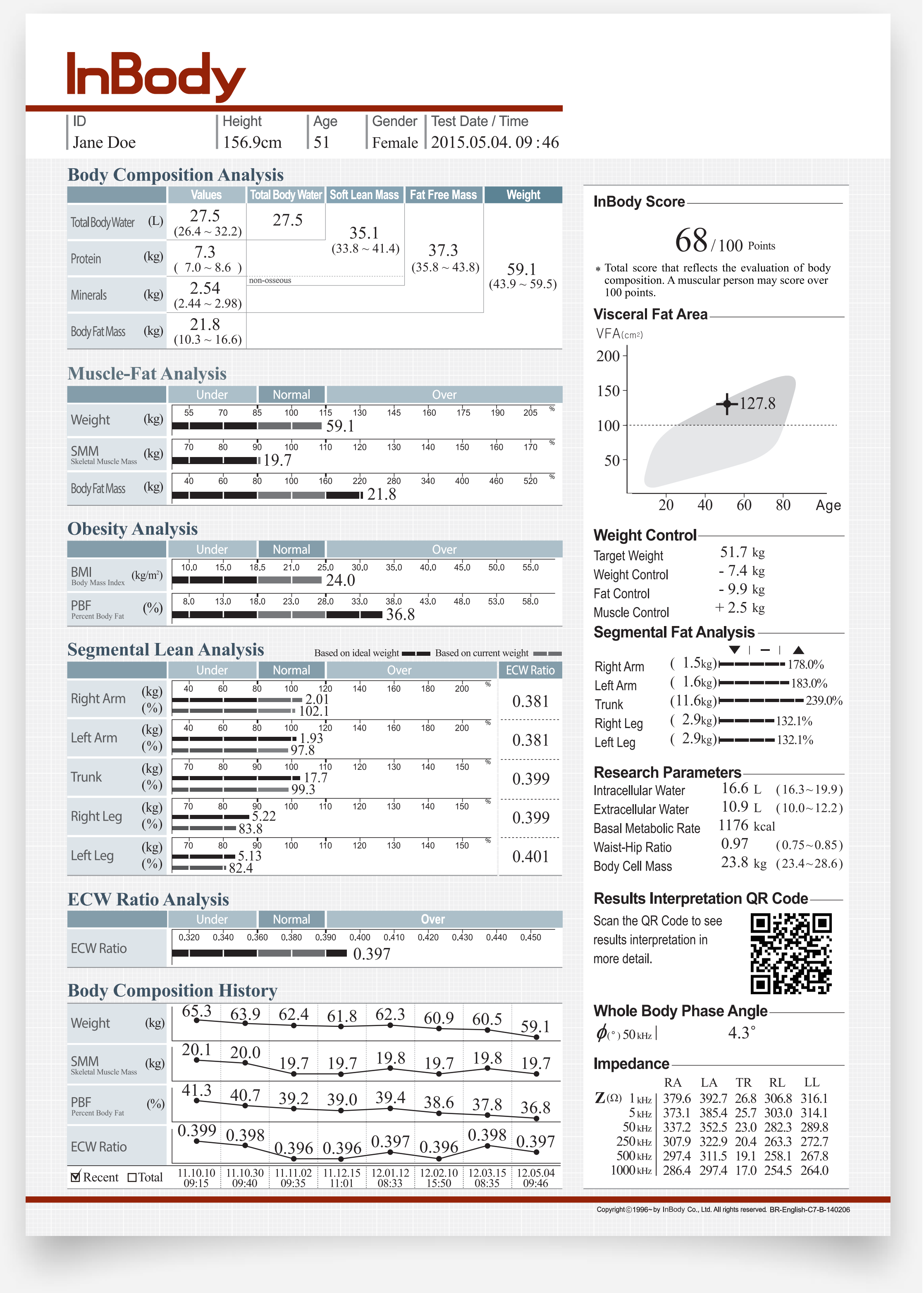
21 Calder, P. C., Carr, A. C., Gombart, A. F. & Eggersdorfer, M. (2020). Optimal Nutritional Status for a Well-Functioning Immune System is an Important Factor to Protect Against Viral Infections. Preprints, 2020030199.
22 Köhnke, K. (2011). Der Wasserhaushalt und die ernährungsphysiologische Bedeutung von Wasser und Getränken. Ernährungsumschau 1: 88-95.
23 Leach, R. M., Brotherton, A., Stroud, M., Richard Thompso, R. (2013). Nutrition and fluid balance must be taken seriously. BMJ 346.
24 https://www.mayoclinic.org/diseases-conditions/edema/symptoms-causes/syc-20366493?p=1

# InBody 770 Body Composition Analysis

## The direct segmental multi-frequency measurement / bioelectrical impedance analysis (DSM-MFBIA) from InBody

Numerous indicators of the immune system can be determined using body composition analysis. The following pages will show how the below points can be evaluated and which statements can be derived about the immune system.

- the Health of the Cells — learn more
- the Skeletal Muscle Mass — learn more
- the Visceral Fat — learn more
- the Body Water & Water Balance — learn more




→ to the result sheet interpretation

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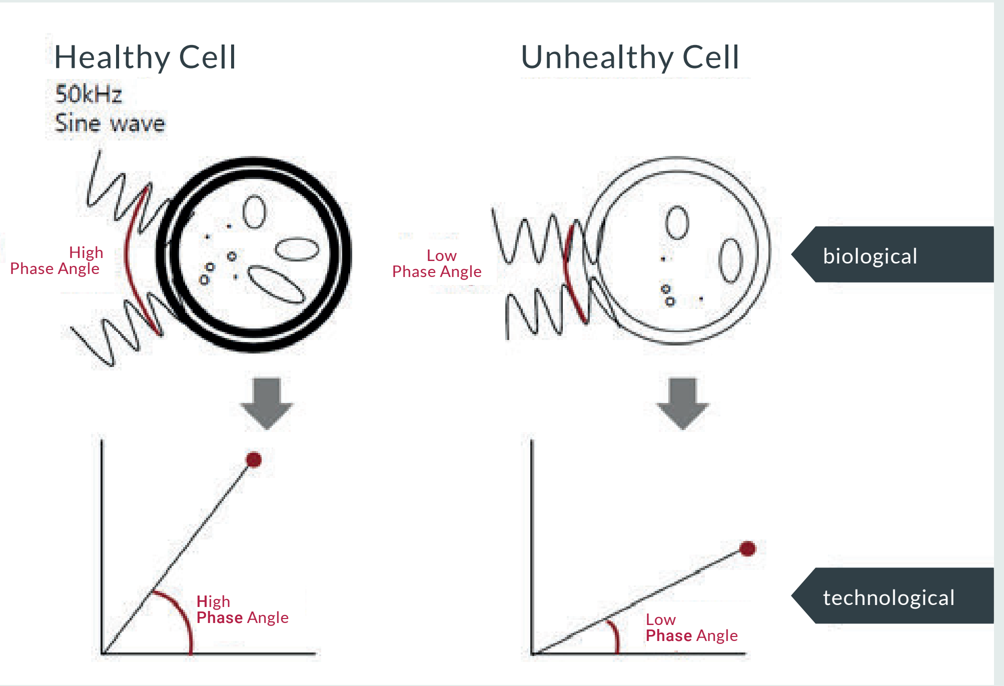
# Phase Angle




In order to measure the phase angle, a current pulse of 50 kHz is sent through the cell. Depending on the state of the cell membrane, there will be a delay of the voltage curve, causing a shift between the current and voltage curve (phase shift). A large delay of the voltage curve is the result of an intact and healthy cell. In case of a damaged cell, there is a smaller delay, therefore a smaller phase shift. A small phase angle (shift) often occurs in combination with low muscle mass and simultaneous edema formation.

## An indicator of cell health

Cell health can be determined using bioelectrical impedance analysis. To do this, the phase angle is determined. The phase angle is used for assessing the health of the human body and the nutritional status of the cells [25,26]. The larger the phase angle, the more resistant and healthier the cell membranes [25,27]. A small phase angle is associated with malnutrition and mortality rate [28,29].

### High phase angle = healthy cell

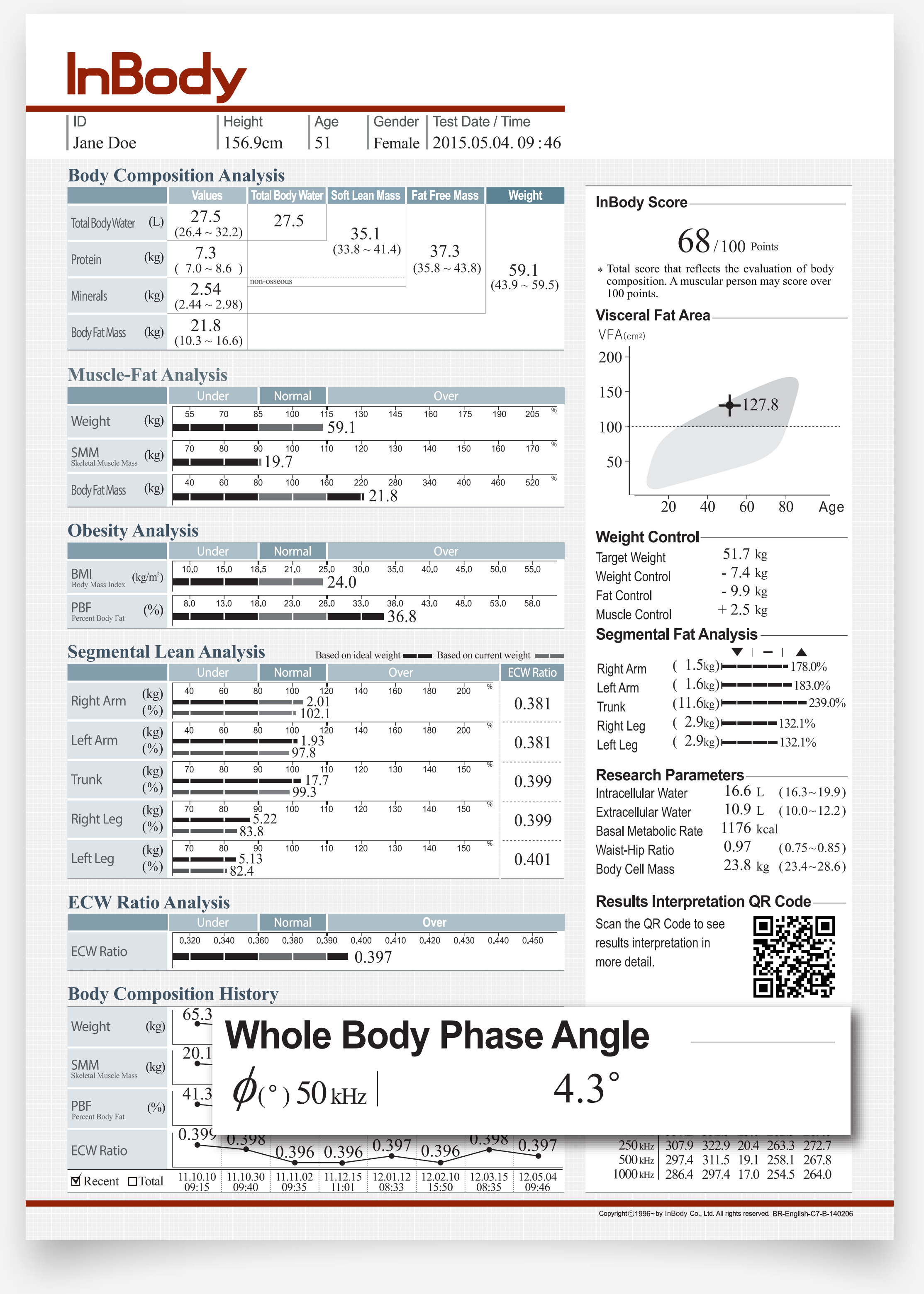
Above 3.5° [25,27]

- Active immune system
- Good food supply
- Healthy water ratio
- Rapid regeneration

### Low phase angle = unhealthy cell

Below 3.5° [25,27]

- Weak immune system
- Malnutrition
- Water retention
- Low muscle mass




25 Kim, H. S. et al (2015). Clinical Application of Bioelectrical Impedance Analysis and its Phase Angle for Nutritional Assessment of Critically Ill Patients. Journal of the Korean Society for Parenteral and Enteral Nutrition, 7(2), 54-61.
26 Mattar J, et al. Application of total body bioimpedance to the critically ill patient. New Horizons 1995, Volume 4, No, 4: 493-503.
27 Al-Kalaldeh, M., et al (2018). Assessment of nutritional status of critically ill patients using the malnutrition universal screening tool and phase angle. Topics in Clinical Nutrition, 33(2), 134-143.
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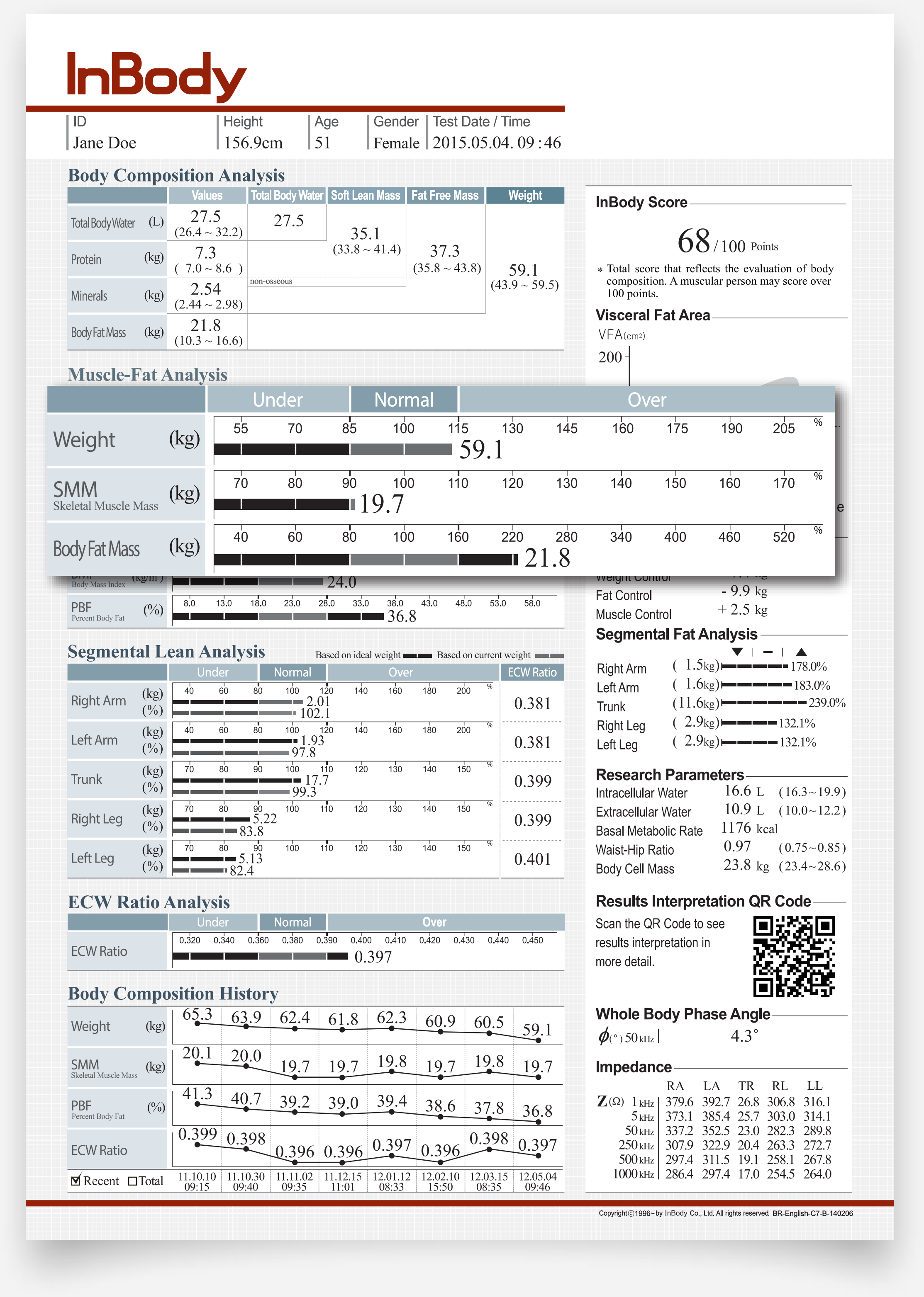
29 Ott M, et al. (1995). Bioelectrical impedance analysis as a predictor of survival in patients with human immunodeficiency virus infection. Journal of Acquired Immune Deficiency Syndrome and Human Retrovirology, 9:20-25.

START

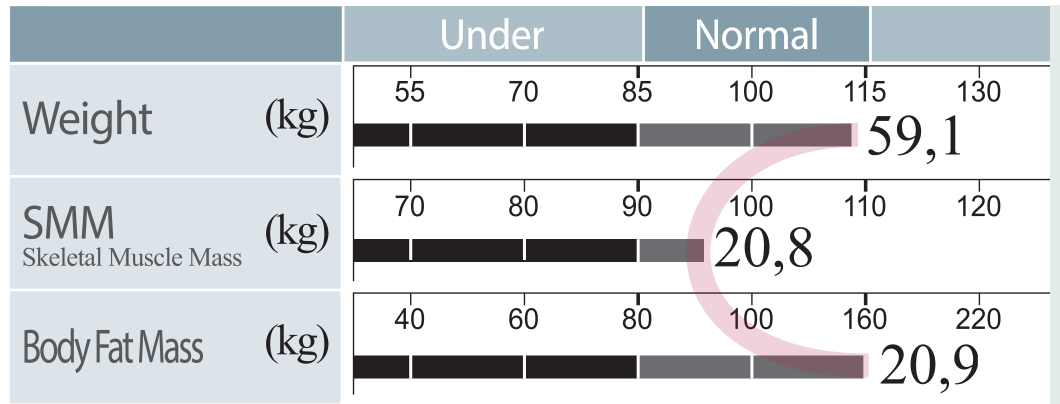
## Skeletal Muscle Mass

### The relationship between muscle mass, weight and body fat mass

Physical activity has proven to be an effective medicine for people. It has positive effects on strengthening the immune system, increasing skeletal muscle mass, reducing body fat mass, increasing bone density [8,9] and thus lowering the risk of diseases such as type 2 diabetes mellitus, obesity, cardiovascular diseases and some types of cancer [10]. Through movement and muscular contractions, myokines are produced in the muscle cells, which promote the build-up of T lymphocytes to strengthen the immune system [7,8].

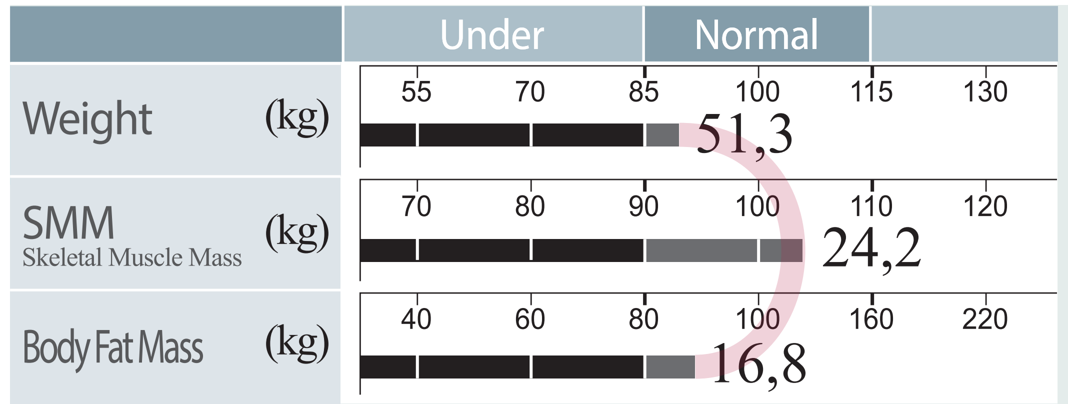



### The C-shape




A "C" stands for a weak body type. Relative to your own body weight, a C-shape has relatively less muscle mass than fat mass. Too low muscle mass (sarcopenia) increases the risk of numerous complications, such as cardiovascular diseases, osteoporosis and frailty [11,30,31]. It is therefore advisable to build up sufficient muscle mass to prevent possible complications.

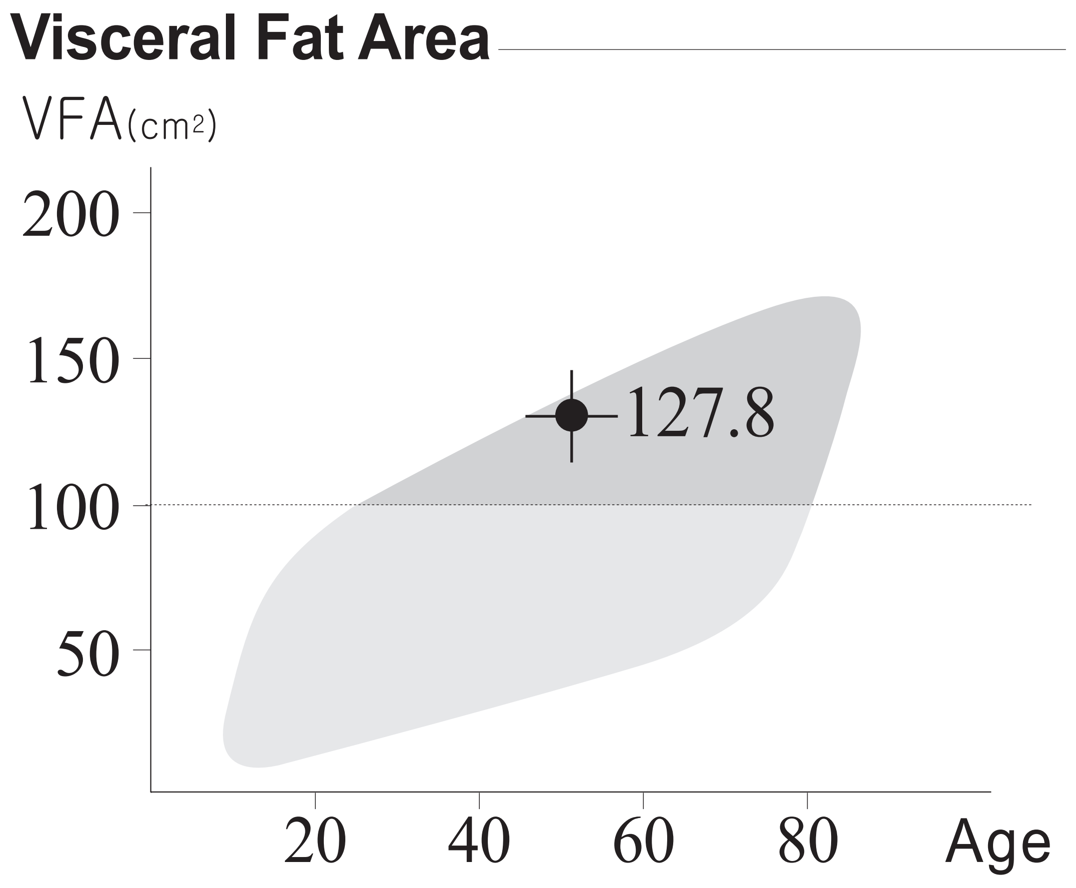
### The D-shape




A "D" stands for an athletic body type. Relative to your own body weight, a D-shape has relatively more muscle mass than fat mass. High muscle mass is related to a higher number of immune cells in the bl ood, therefore indicating a stronger immune system [6]. Muscle building training leads to an increase of muscle mass, and can therefore be a basis for a strong immu ne system [6, 9].

30 He, H., Liu, Y., Tian, Q., Papasian, C. J., Hu, T., & Deng, H. W. (2016). Relationship of sarcopenia and body composition with osteoporosis. Osteoporosis International, 27(2), 473-482.
31 Evans, W. J., Paolisso, G., Abbatecola, A. M., Corsonello, A., Bustacchini, S., Strollo, F., & Lattanzio, F. (2010). Frailty and muscle metabolism dysregulation in the elderly. Biogerontology, 11(5), 527-536.

# Visceral Fat

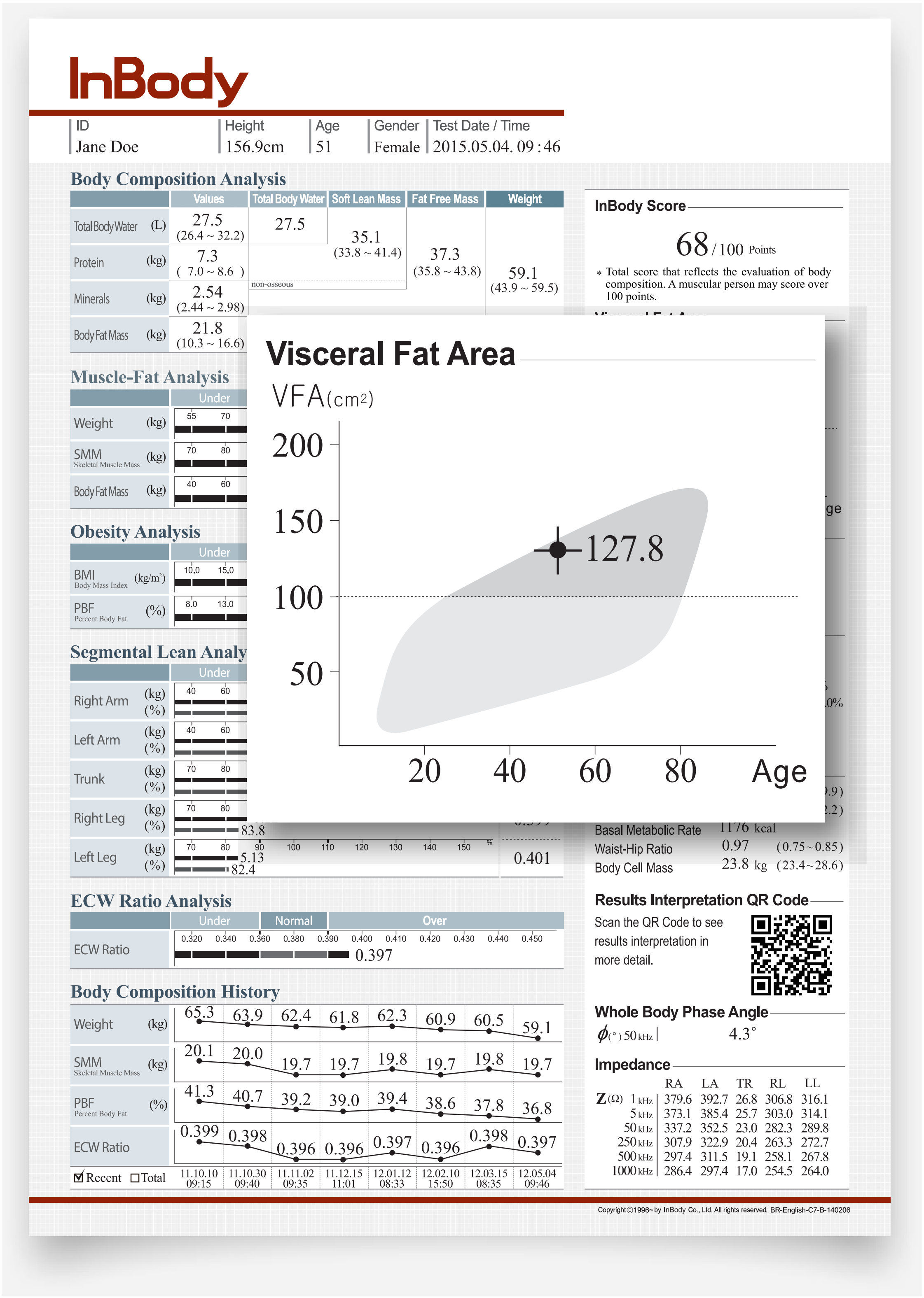



## Underestimated health risk

Visceral fat refers to the fat in the free abdominal cavity, which surrounds the internal organs and is not visible from the outside. Current literature shows that visceral fat in particular, in contrast to subcutaneous fat, emits more inflammatory messengers and thus impairs the functions of the immune system [12]. Studies show that increased visceral fat is correlated with an increased production of adipokines [13]. These adipokines, together with the increased accumulation of macrophages, increase the inflammatory processes and the development of insulin resistance [17]. Therefore, these are associated with an increased risk of secondary diseases and thus also a weakened immune system [12, 17]. Regular physical activity can reduce the visceral fat, thus preventing the harmful inflammatory reactions and improving the immune system [8,20].

**Interpretation:** If the visceral fat area is above the medically recognized risk limit of 100 cm², there is an increased risk for the numerous secondary diseases related to high visceral fat (hypertension, cardiovascular diseases, diabetes II, etc.) [12-18]. In addition, with aging visceral fat can increase which also increases the associated risk of complications, see the grey cloud. To prevent this pattern, people should take care of their visceral fat by changing their lifestyle.

**Conclusion:** Aim for a visceral fat area in the light grey area (below 100 cm²).



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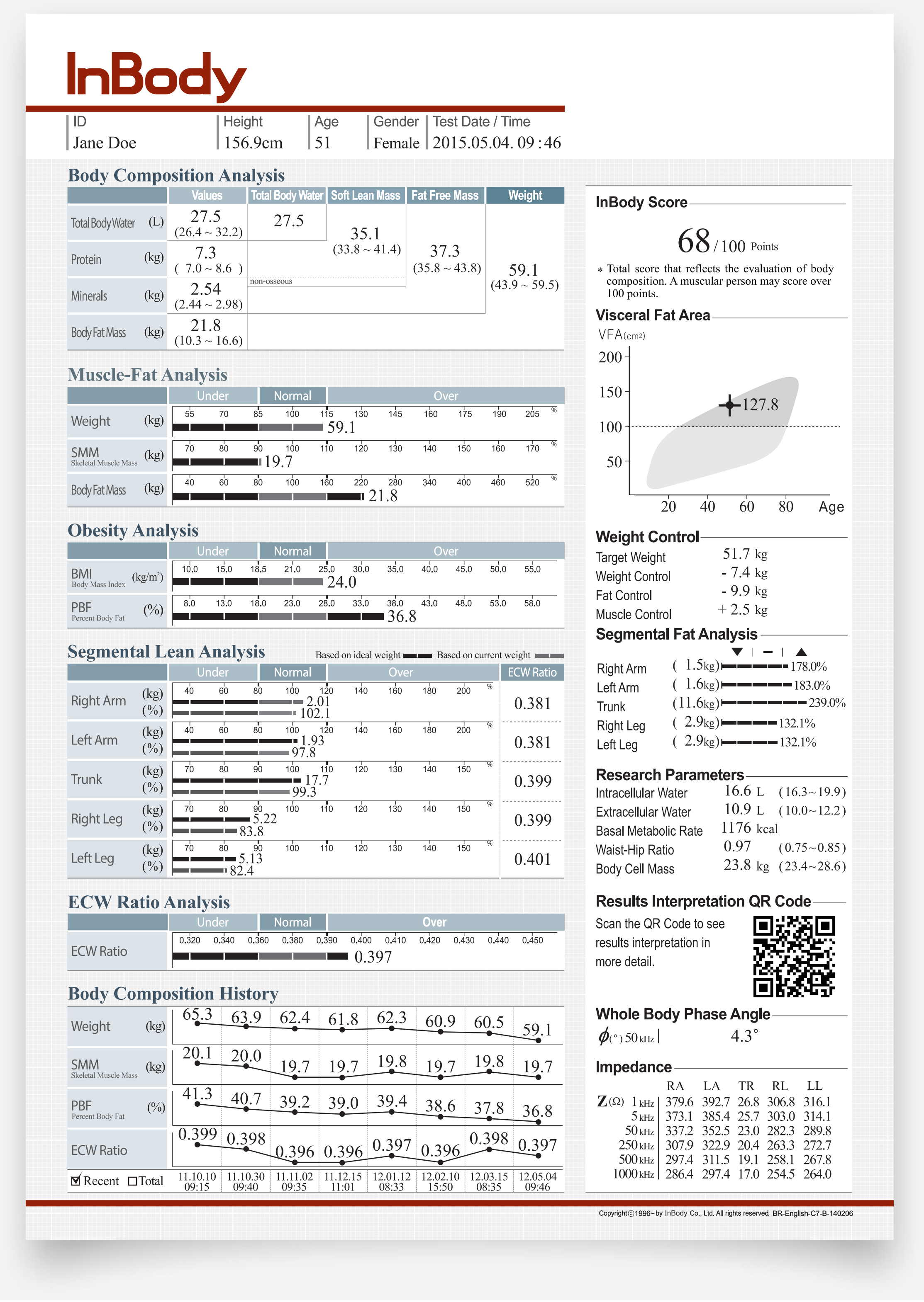
# Body Water & Water Balance

The normal range between 0.360-0.390 is based on the knowledge that in a healthy person the ratio between intra- and extracellular water should be 62% to 38% resoectivily. The ECW ratio is therefore calculated using the formula ECW / TBW (total body water).

## Solvents, building materials, temperature regulators and means of transport

The body water describes the water contained in the body fluids. It is composed of the intracellular and extracellular body water and serves as a solvent, building material, temperature regulator and means of transport. Balanced body water plays an essential role in the fight against diseases and injury [23]. The body water ensures the transport of numerous substances in the liquid compartments. These include supplying the cells with nutrients and excreting urinary substances [22]. An increased loss of water from the blood and tissue, negatively affects the flow properties of the blood and urinary substances are no longer excreted to a sufficient extent. A sufficient supply of oxygen to the muscle and brain cells can therefore no longer be guaranteed. With inflammation, the permeability of the blood vessels often changes [32], which is why water can accumulate in the surrounding tissue. Water retention is related to many diseases such as cardiovascular, kidney and liver diseases [24] and can support the development of diseases [23].

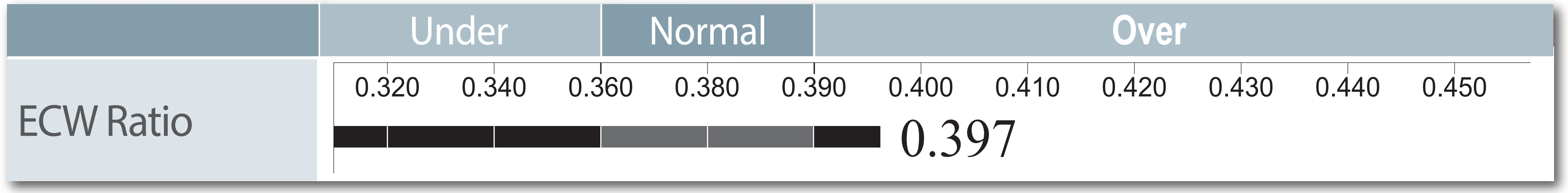



The ECW ratio is the ratio of extracellular water to total body water and an important indicator for a balanced water balance.

= **Normal range**: 0.360 - 0.390

> Normal range
Water retention, edema, (extremely) low intracellular water

< Normal range:
Dehydration, high intracellular water




32 Pober, J. S., & Sessa, W. C. (2014). Inflammation and the blood microvascular system. Cold Spring Harbor perspectives in biology, 7(1), a016345. https://doi.org/10.1101/cshperspect.a016345

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InBody is used successfully in more than 80 countries worldwide. Almost 130,000 health facilities worldwide rely on the InBody measuring systems. In addition to fitness and health facilities and physiotherapy, these include leading DAX companies, medical care centers, hospitals, Olympic training centers and well-known research institutions.

InBody is easy to use, the test is quick less than a minute, non-invasive and above all provides accurate results. At the international level, numerous studies(+2800 thesis) with InBody are carried out in medical research and sports science.

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Page 5: Illustration lymphocytes (Adobe Stock/fotomek)
Page 6: Schematic representation of leukocytes (Adobe Stock/timonina)
Page 7: Human muscles (Adobe Stock/adimas)
Page 8: Visceral fat(InBody)
Page 9: water (Fotolia/Robert)
Page 10: InBody 770 during measurement (InBody)
Page 11: Schematic representation of the phase angle (InBody)
Page 12: Visualization of the C and D shapes (InBody)
Page 14: Visualization of body water analysis (InBody)
Page 15: InBody devices (InBody)