Anthropometric Changes in Students Resulting from the Advanced Combat Course at Escuela Militar de Cadetes

2

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Abstract

Background. During military training, students in training schools undergo the Advanced Combat Course (ACC). This course is effective to obtain technical and tactical results for operations. However, there are physical results that cannot be evaluated by using a parameter, such as body mass index, making the understanding of the effects of the ACC on anthropometric conditions necessary to indirectly evaluate the course's components. These results can aid in making potential mid- or long-term adjustments so that training objectives are achieved, without detriment to the participants' well-being. ***Objective.*** This study's objective was to determine the anthropometric changes of the military personnel participating in the Advanced Combat Course and its significant physical repercussions, which can be used as an indicator of the improvement or not of the individual's physical fitness. ***Materials and methods.*** A longitudinal study was conducted with 69 military personnel (56 men and 13 women) in training at the Colombian Army's *Escuela Militar de Cadetes*. The participants signed an informed consent. An anthropometric assessment of height, weight, and waist circumference was performed before and after the ACC. Body composition was also evaluated using electrical bioimpedance (SECA 525), and the behavior of the data was established by using the SPSS Ver. 21 statistical program. The statistical significance of the data was then established by using Student's t-test method for paired data. ***Results.*** The varia-

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bles of WEIGHT, body mass index (BMI), relative fat mass (RFM), absolute fat mass (AFM), visceral adipose tissue (VAT), extracellular fluid (ECF), and phase angle (PhA) had statistically significant changes, meaning that the ACC's physical burden produces changes on these variables. There were no statistically significant changes in the fat-free mass (FFM), skeletal muscle mass (SMM), total body water (TBW), and waist circunference (WC). ***Conclusions.*** While the physical load involved in the 8-week advanced combat course produces changes in all the anthropometric variables evaluated through bioelectrical impedeance analysis, only a few variables present statistically significant changes. However, they are unproved concerning fat-free mass, skeletal muscle, total water, and waist circumference.

Keywords: anthropometry, adiposity indicators, body composition, body fat percentage, body mass index, electrical bioimpedance, fat mass index

Introduction

During one of the training phases of their stay at *Escuela Militar de Cadetes "General José María Córdova",* students must complete the Advanced Combat Course (ACC). This instruction and training program prepares and certifies National Army training school students as troop and field commanders to lead squads and small units in simulated combat environments in the technical, tactical, humanistic, and physical areas (1) (2). It aims to develop the necessary skills for students to preserve their lives, as well as those of their superiors and subordinates, while achieving the mission objective in operational situations that resemble real life as closely as possible. The course involves both academic and physical aspects. It is worth noting that the results achieved determine the students' ascent in military rank, giving the course a high quota of importance.

For eight weeks, the students face situations that test their physiological and physical conditions to test their physical performance. The six levels prior to the course involve elements, like strength, endurance, speed, and conditional abilities, like flexibility, balance, agility, mobility, and coordination skills (3). These skills vary per student and are influenced by the course's high demands, the limited time to achieve them, the course site's hostile climate, the participants' apparel, and the additional weight of the campaign equipment.

It is important to point out that exercise, in general, offers health benefits in non-military populations (4). However, under adverse operational and climatic situations, exercise can produce undesired impacts on those being trained; this has been described in reviews by several military entities concerning short training courses (5). It has also been documented that exercise can produce changes in the subjects' body composition (6) (7) and in other aspects of physical fitness, which are not the subject of this chapter.

The results of this work show the ACC's effects on the students' anthropometric conditions, indirectly evaluating the course's components, so that, in the mid- or long-term, necessary adjustments can be made to achieve the training objectives without detriment to the participants' well-being.

As in many other countries, in Colombia, anthropometric criteria, such as indices based on weight, height, and ratio (body mass index - BMI), have traditionally been used to determine obesity, malnutrition, and eating disorders. This index is calculated by dividing a person's weight in kilograms by the square of their height in meters (kg/m^2). However, these variables have little sensitivity to monitor the response to the process faced by the patient, athlete, or, in this case, the training school student.

To qualify this process, the evaluation of the segmental body composition is ideal. Moreover, understanding the different segments, like body fat, and their distribution needs greater attention concerning the etiology of cardiovascular disease, hypertension, and type 2 diabetes, chronic diseases that are now considered to have their "incubation period" during childhood and adolescence (8).

The BMI provides the fastest measure of overweight and obesity in a population; it is used indiscriminately for both genders and adults of all ages. However, from the point of view of sports medicine, nutrition, among other knowledge lines, is a measure that is too succinct and, in some cases, apparent and inadequate to determine the evaluated subject's nutritional status effectively. Studies have shown that the BMI shows low reliability to estimate adiposity at an individual level, particularly in men and when the BMI is less than 30 kg/m^2 (9).

Thus, the Research Center for Physical Culture (CICFI in Spanish) at *Escuela Militar de Cadetes "General José María Córdova"* set out to determine the effect of the ACC on the military cadet personnel's body composition through a more sensitive method, such as electrical bioimpedance, to understand the course's impact on its structure. The course's protocols and use were exhaustively applied to determine its impact on the subject's different segments before and at the end of the course.

Sensitivity and specificity of bioelectrical impedance analysis in anthropometry

The study of body composition is a topic of growing interest, which can be used for research and clinical purposes. Because changes in body composition are directly related to health and disease, it is important for health science professionals to know the different methods of assessing and analyzing body composition. Body composition analysis methods are currently divided into three groups, direct, indirect, and double indirect. The direct method is the dissection of corpses. The indirect methods include computerized axial tomography (CAT), magnetic resonance imaging (MRI), dual X-ray absorptiometry (DXA), and plethysmography. Anthropometry and bioelectric impedance (BIA) stand out within the double indirect methods (10).

Historically, body composition has been used mostly because of what has been achieved than what has been investigated; this is the fundamental limitation of the different techniques developed (11). The ideal method to study an individual's body composition would be one in which each and every section of the human organism, like fat, bone, muscle, and water, could be analyzed separately. Therefore, to date, the most comprehensive method is cadaver dissection analysis. Between 1945 and 1956, studies on the bodies of five men and one woman were conducted. Although the results showed considerable differences in fat tissue, they all showed relatively constant values in water (73%), protein (approximately 20%), and around 69 mmol K/kg (12). So far, none of the body composition evaluation methods can be conducted directly on living subjects. Instead, it is done by deriving values from body property measurements. The techniques, in practice, present two errors. The first is a methodological error during the collection of the primary data. The second error is in the assumptions made when the primary data is converted into the final result. The relative magnitude of these errors varies between the techniques (13).

Thus, bioelectrical impedance analysis (BIA) is presented as a simple, inexpensive, and easy-to-use method that provides more information for patient monitoring and evaluation in practice. This non-invasive and portable technique has been used for over a decade for body composition analysis. However, bioelectrical impedance does not directly measure body composition; it measures two parameters, body resistance and reactance (14) (15).

Bioelectrical impedance analysis measures the body's resistance or impedance to a small electrical current, undetectable by the subject. It is based on the fact that lean tissue contains high levels of water and electrolytes and, therefore, acts as an electrical conductor and fat acts as an insulator (13), assuming that total body water is a fixed proportion (73%) of the fat-free mass (16). Electrical bioimpedance is based on the opposition of cells, tissues, or body fluids to the passage of an electrical current generated by the device. Fat-free mass, like muscle and bone, have most of the body's fluids and electrolytes.

Once the the fat-free mass value has been obtained, the fat mass is calculated from the total body weight (15). According to the statement by the National Institutes of Health Technology Assessment Conference (Bethesda, Maryland, 12-14 December 1994), regarding the use of BIA in body composition studies, BIA is more accurate than BMI and, perhaps, even more accurate than skinfold measurement for comparative fat mass estimation (17). Therefore, this apparatus provides direct estimation of total body water. From there, fat-free mass and fat mass are estimated indirectly, through pre-established formulas.

This method's reliability and accuracy can be influenced by several factors, such as the type of instrument, electrode placement points, hydration level, feeding, menstrual cycle, ambient temperature, and the prediction equation used, which is generally close to $r^2 = 0.84$, compared to DXA (18). Therefore, some care should be taken before using bioelectrical impedance to avoid errors. These precautions include not eating or drinking four hours before the test, not exercising 12 hours before, urinating 30 minutes before, not drinking alcohol 24 hours before, and not intaking diuretics in the last seven days (19).

Its variables are impedance (Z), resistance (R), and reactance (Xc). Impedance, Z, which is measured in ohms, is the square root of the sum of R and Xc, and it is frequency-dependent; R is the pure opposition of a biological conductor to the flow of an alternating electric current; Xc is the effect of resistance due to the capacitance (storage of electric charge in a capacitor) produced by the tissue and cell membranes' interfaces. Capacitance causes the current to leave the voltage behind, creating a phase shift. This change is quantified geometrically as the angular transformation of the ratio of Xc to R, or the phase angle (20).

The phase angle (PhA) is the most established BIA parameter for diagnosing malnutrition and clinical prognosis, both associated with changes in cell membrane integrity and alterations in fluid balance. The PhA expresses changes in the quantity and quality of soft tissue mass (*i.e.*, cell membrane permeability and hydration). Numerous clinical trials propose the PhA as a useful prognostic marker for clinical conditions, such as liver cirrhosis, as well as breast, colon, pancreatic, and lung cancer. It has also been observed in HIV-positive patients. Surgically, there has been a positive association between the PhA and survival (21). A consensus on normal values has yet to be reached. However, the PhA's general behavior has a negative correlation with age. There has also been a positive correlation between BMI and the phase angle in underweight and normal-weight subjects.

Some examples of research using this method of assessing body composition include a study by Madsen *et al.*, 2014 (22) involving healthy young men in India. The study verified the effects of a cycling program on these subjects' body composition. Another study by Saladin (23), involving patients with eating disorders, evaluated the changes in their body composition during treatment. Camina-Martin *et al.*, 2015 (24) carried out a study with older men with and without dementia, comparing anthropometry and bioelectrical impedance to verify the relationship between dementia and body composition. Esco *et al.*, 2015 (25) assessed female university athletes to evaluate this method's reliability for measuring body composition in different body segments.

In 1994, Núñez *et al.*, studied body composition in young women. They reported a positive correlation between BIA and anthropometry, proposing this technique as an alternative to measuring body composition in homogeneous populations with stable weight. Other authors do not favor its use in obese or very skinny people (26). Available information indicates that bioelectrical impedance is not useful to measure acute body fat changes, although it can characterize long-term changes (17). Currently, some propose that the fundamental value of this technique is in epidemiological monitoring to estimate lean mass (13).

This method's primary advantages are that it allows differentiating between fat and lean tissue and monitors weight loss composition. Some models provide a segmental analysis that is simple and easy to run and highly reliable for large-scale studies. It also allows printing the results immediately. Moreover, most are portable, non-invasive, low risk, and low cost, compared to other high-tech methods, and high predictive value (extensive validations). They also present excellent consistency for repeated measurements (27). Some of its disadvantages are that it is not recommended for use in patients with pacemakers and it is not as accurate as the 4-compartment "gold standard" models. Also, there are no versions available for children under five years of age, patients with hydroelectrolyte balance disorders, and most patients must be able to stand on the platform in the foot models.

It also has application limitations in patients presenting fluid retention, peripheral edema, and hydrostatic problems or using diuretic medication or who have some type of amputation or anatomical deficit of a limb. It is not a suitable method for athletes because it has a 3% error rate, which is too high to provide proper information on the athlete's health status. Furthermore, a minor change in electrode location can produce a 2% variability in the results on different days (27,16).

Methods

This longitudinal study involved seventh-level cadets from *Escuela Militar de Cadetes* who, by the second semester of 2018, were required to participate in the Advanced Combat Course as a graduation requirement for their elective year in 2018. From a universe of 120 cadets, a simple random selection of 80 subjects was made, according to instructions given to the Cadet Group Commander. Ultimately, a total of 69 healthy subjects (13 females and 58 males) between the ages of 18 and 24 (57.5% of the total course population) participated, guaranteeing a statistically representative sample. The inclusion criteria considered healthy men and women between the ages of 18 and 24, students in the seventh-level military training who had taken and passed the Military School's obligatory levels of teaching. The exclusion criteria included cadets who did not sign the informed consent, were withdrawn or did not complete the ACC satisfactorily, or did not have the pre- and post-course anthropometric evaluations. Those with incomplete values or if typing errors were found during data processing, selection, and analysis were also excluded. To avoid bias, the BIA protocol was applied exhaustively, based on the recommendations already mentioned by the authors. Pre- and post-course testing was performed early in the day (between 4:30 and 6:00 a.m.), when the participants had an empty stomach.

The following phases were carried out for this study:

1. Identification of the personnel taking the ACC in the second half of 2018

2. Informing the population, explaining the study's reason and purpose.
3. Subjects were informed individually of the risks and benefits of voluntarily participating in the study.
4. Subjects signed the informed consent form and voluntarily entered the study.
5. Anthropometry by BIA was performed, according to the protocol, before departure to ACC with personnel meeting the inclusion and exclusion criteria.
6. Anthropometry by BIA was performed two to five days after the completion of the ACC. Again, taking into account the protocol.

A total of 11 (dependent) variables were evaluated before and after the ACC (Table 1). Each variable was assigned a number corresponding to the period in which it was evaluated: (1) corresponds to the pre-course measurement and (2) corresponds to its measurement post-course. Example: BMI1 - value taken before the start of the course and BMI2 - value after the end of the course.

Table 1. Variable Matrix

Name	**Abbreviation**	**Conceptual Definition of the Variable** (28)	**Indicator**	**Measurement Scale**
Independent Variables				
Age	-	No. Years old	Years of service	Continuous, in years
Size	-	Distance from the measuring plane to the vertex in a standing position	Centimeter distance	Continuous, in centimeters
Gender	-	Biological distinction between men and women	M: Male F: Female	Nominal
Dependent variables				
Weight	Weight	Mass in kilograms	Grams of weight	Continuous, in kilograms

Continuous table

Name	Abbre-viation	Conceptual Definition of the Variable (28)	Indicator	Measurement Scale
Body Mass Index	BMI	Relationship between weight and height used as an indicator of nutritional status	Weight / Size^2	Continue, decimal number
Relative Fat Mass	RFM	Measurement calculated using size and waist circumference.	Grams of weight	Continuous, in kilograms
Absolute Fat Mass	AFM	Mass in kilograms	Grams of weight	Continuous, in kilograms
Visceral adipose tissue	VAT	Absolute value in litres	Volume in litres	Continuous, in liters
Fat Free Mass	FFM	Mass that includes bone, muscle, extracellular water, nerve tissue, and all other cells that are not fat or adipocytes	Grams of weight	Continuous, in kilograms
Skeletal Muscle Mass	SMM	Muscle mass in kilograms	Grams of weight	Continue, in kilograms
Total Body Water	TBW	Absolute value in liters	Volume in liters	Continuous, in liters
Extrace-llular fluid	ECF	Relative value in %	Percentage	Continuous, in percentage
Waist Circum-ference	WC	Measurement in centimeters of the largest perimeter around the abdomen between the lower edge of the rib cage and the iliac crest	Centimeters	Continuous, in centimeters
Phase angle	PhA	Changes in cell membrane integrity and alterations in fluid balance	Whole number	Continuous, decimal number

Source: Material created by the author.

Results

A total of 69 subjects belonging to *Escuela Militar de Cadetes "General José María Córdova"* were evaluated. The distribution by gender was 13 women (18.5%) and 56 men (81.5%). The mean age of the general population was 21.15 ± 1.14 years. Their average height was 1.68 ± 0.67 centimeters (1.51 centimeters minimum and 1.81 maximum).

Table 2 shows the 11 anthropometric variables analyzed with their respective descriptive data.

Table 2. Description of anthropometric variables of ESMIC cadets. Pre (1) and post (2) advanced combat course values

Variable	Average	N	Standard deviation	Typical error of the average
Weight 1	66.574	69	8.8313	1.0632
Weight 2	64.323	69	7.7093	0.9281
BMI1	23.3165	69	2.16537	0.26068
BMI2	22.5168	69	1.80848	0.21772
RFM1	17.9713	69	7.47749	0.90018
RFM2	15.3980	69	6.37592	0.76757
AFM1	12.0994	69	5.40873	0.65113
AFM2	9.9172	69	4.13968	0.49836
VAT1	1.4096	69	0.42321	0.05095
VAT2	0.9961	69	0.25037	0.03014
FFM1	54.4745	69	7.66051	0.92222
FFM2	54.4059	69	7.42892	0.89434
SMM1	26.3086	69	4.58379	0.55182
SMM2	25.7114	69	4.09703	0.49322
TBW1	39.645	69	5.5256	0.6652
TBW2	39.646	69	5.3657	0.6460
ECF1	15.749	69	2.0971	0.2525
ECF2	16.070	69	2.1561	0.2596
WC1	0.7414	69	0.04806	0.00579
WC2	0.7410	69	0.04766	0.00574
PhA1	7.561	69	0.6411	0.0772
PhA2	7.226	69	0.6646	0.0800

N: subjects of the sample.
Source: Material created by the author.

The table shows a weight difference between the pre-ACC intake of 66.57 ± 8.8 kg and a post-ACC of 64.32 ± 7.7 kg, with an average difference of 2.25 kg less after the course. It also shows a pre-ACC BMI value of 23.32 ± 0.26 and a post-ACC BMI of 22.5 ± 0.21, a difference of 0.79 less at the end of the course.

In general, it can be observed that there is a decrease in all the variables, with the exception of the values of total water and extracellular fluid.

The first step was to determine the data normality by applying the Kolmogorov –Smirnov and Shapiro-Wilk tests, with 95% confidence interval. The results are shown in Table 3. We checked the significance level; the distribution was considered not normal if it was < 0.05 and normal if it was > 0.05.

Table 3. Summary of processing of normality test cases

	Kolmogorov-Smirnov			**Shapiro-Wilk**		
	Statistical	N	Sig.	Statistical	N	Sig.
Age	0.189	69	0.000	0.914	69	0.000
Weight1	0.075	69	0.200*	0.983	69	0.486
Weight2	0.083	69	0.200*	0.989	69	0.804
Height	0.081	69	0.200*	0.983	69	0.457
BMI1	0.065	69	0.200*	0.978	69	0.266
BMI2	0.076	69	0.200*	0.985	69	0.552
RFM1	0.068	69	0.200*	0.972	69	0.123
RFM2	0.108	69	0.045	0.945	69	0.005
AFM1	0.074	69	0.200*	0.970	69	0.092
AFM2	0.094	69	0.200*	0.974	69	0.155
VAT1	0.108	69	0.046	0.952	69	0.010
VAT2	0.070	69	0.200*	0.992	69	0.948
FFM1	0.130	69	0.006	0.972	69	0.128
FFM2	0.140	69	0.002	0.973	69	0.139
SMM1	0.167	69	0.000	0.945	69	0.004
SMM2	0.123	69	0.012	0.959	69	0.025
TBW1	0.106	69	0.052	0.980	69	0.337
TBW2	0.119	69	0.016	0.979	69	0.290
ECF1	0.056	69	0.200*	0.991	69	0.904
ECF2	0.099	69	0.091	0.984	69	0.497
WC1	0.092	69	0.200*	0.973	69	0.149
WC2	0.097	69	0.183	0.974	69	0.162
PhA1	0.100	69	0.085	0.979	69	0.291
PhA2	0.096	69	0.191	0.982	69	0.431

* This is a lower limit of true significance.
Source: Material created by the author

Based on the results of the tests conducted, it can be confirmed that the statistics of all the variables analyzed were > 0.05. Therefore, they are considered of normal distribution.

Following the aforementioned, we decided to use Student's t test for a related sample, with a 95% confidence interval; that is, a 5% error. We started with a null hypothesis, H0, where no significant difference in the values was determined. An alternative hypothesis, H1,was used where there was a significant difference (Table 4).

Table 4. Application of Student's t test

	Related Differences						
	Average	**Common deviation**	**Typical average error**	**95% Confidence interval for the difference**		**t**	**Signi-ficance**
				Lower	**Higher**		
Weight1 - Weight2	2.2507	2.4313	0.2927	1.6667	2.8348	7.690	0.000
BMI1 - BMI2	0.79971	0.84063	0.10120	0.59777	1.00165	7.902	0.000
RFM1 - RFM2	2.57333	2.78233	0.33495	1.90494	3.24172	7.683	0.000
AFM1 - AFM2	2.18217	2.26404	0.27256	1.63829	2.72606	8.006	0.000
VAT1 - VAT2	0.41348	0.35192	0.04237	0.32894	0.49802	9.760	0.000
FFM1 - FFM2	0.06855	1.39951	0.16848	-0.26765	0.40475	0.407	0.685
SMM1 - SMM2	0.59710	1.71169	0.20606	0.18591	1.00829	2.898	0.005
TBW1 - TBW2	-0.0014	1.0825	0.1303	-0.2615	0.2586	-0.011	0.991
ECF1 - ECF2	-0.3203	0.6298	0.0758	-0.4716	-0.1690	-4.224	0.000
WC1 - WC2	0.00043	0.00361	0.00043	-0.00043	0.00130	1.000	0.321
PhA1 - PhA2	0.3348	0.3584	0.0432	0.2487	0.4209	7.758	0.000

Source: Material created by the author

The interpretation of Table 4 shows that if the p (value) or significance was < 0.05, the null hypothesis, Ho, is rejected. Thus, the alternate hypothesis, H1, is true.

It can be stated that the variables of Weight, BMI, RFM, AFM, VAT, ECF, and PhA had statistically significant changes. In other words, the ACC's physical burden produces changes in the above variables. On the other hand, there were no statistically significant changes in the FFM, SMM, TBW, and WC.

Discussion

After taking the Advanced Combat Course, the values that decreased significantly from the initial ones were weight, body mass index, relative and absolute fat mass, visceral adipose tissue, extracellular fluid, and phase angle. These results are positive from a medical, nutritional, and general health perspective, contributing to the reduction of cardiovascular risk and ideals according to anthropometric parameters.

The variables with the most significant percentage of change were those related to fat mass, in percentage, and total weight within the organism. This change is fundamentally due to the students' aerobic training (29), which has lipids as its main source of energy. The variables of body weight and BMI also underwent a significant decrease. On the one hand, because weight was lost, reducing the total amount of body fat, on the other, because of the amount of extracellular water. No increase was found in muscle mass and fat-free mass.

The variables that did not present changes, such as fat-free mass, skeletal muscle, total water, and waist circumference respond to the course's most significant conditions and objective, which involve the soldier's technical, tactical, psychological, and, to a lesser degree, physical preparation for military operations, especially in the sites of these operations, which are generally hostile combat zones that present climate, food, hydration, and adverse psychological condition-related hardships. These are truly the conditions that the Colombian soldiers face in their theaters of operations after graduating and going out to exercise their careers; the ACC seeks to improve their conditions of resistance and tolerance to these types of noxas. From the physical point of view, its objective is not to gain muscle mass or power of any kind.

It should be noted that muscle mass increase is largely determined by predominance of protein synthesis over its destruction (29); predominance, which in strength-training athletes can be 3.9% higher than the amount of protein measured in post-training (30). However, in the case of the military students' training, it is possible that because of the high protein anabolism resulting from the resistance training and associated with high temperatures and low nutritional intake, increased protein synthesis may be surpassed by the catabolic processes that lead to the accumulation of continuous aerobic work sessions throughout the course; this could explain why no changes are seen in these variables.

Concerning the phase angle, it is considered that acute exposure (eight weeks) in healthy subjects without previous pathological conditions does not impact the values significantly. Therefore, not unlike the previous, they were not reflected in the final effects.

This study's results indicate that the objectively elaborated and acutely applied structured training content allows participants in this type of course to present body variations, despite the inclement climate, emotional load, and stress of the simulated operation areas. Moreover, it produces anthropometry improvements, secondary to the types of imposed loads associated with the nutritional models that accompany these processes.

The study shows that the body variations were adequate and are not harmful to the individual's health. They are also a fundamental part of the military personnel's training and reality in their areas of operations.

These results will be beneficial in the future in the short, medium, and long term, as long as the application of the loads in this type of course can be technologically advanced and objective, oriented more and more towards improving the anthropometric conditions of our soldiers.

Conclusions

It can be concluded that after the eight weeks of training, the variables of weight, body mass index, relative and absolute fat mass, visceral adipose tissue, extracellular fluid, and phase angle presented statistically significant changes. In other words, the physical load by the ACC affects changes in the variables mentioned.

There were no statistically significant changes found in fat-free mass, skeletal muscle, total water, and waist circumference.

Future studies should try to establish, in addition to anthropometric parameters, evidence of nutritional and water inputs to try to strengthen these variables, if necessary.

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