

Physical fitness and nutritional status in female adolescents with anorexia nervosa

Aptidão física e estado nutricional em adolescentes do sexo feminino com anorexia nervosa

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ABSTRACT

Objective

This study aimed to determine whether physical fitness is related to nutritional status in a sample of female adolescents with anorexia nervosa, to contrast the nourished and undernourished patients, and to compare the physical fitness in these patients with normative data of healthy subjects stratified by age and gender.

Methods

Nutritional status was determined using the body mass index Z-score, fat mass, fat-free mass (bioelectrical impedance analysis), and the Controlling Nutritional Status score in 15 anorexic adolescents with 14.3 ± 1.6 years. Physical fitness was assessed using the ALPHA-Fitness Battery (handgrip strength, standing broad jump, 4x10m shuttle run, and 20m shuttle run tests).

Results

Handgrip strength was significantly associated with all variables of nutritional status, except with the three blood components of the Controlling Nutritional Status score. The undernourished anorexic patients showed significantly worse physical fitness than the nourished anorexic patients in all tests, except in the standing broad jump and the 4x10m shuttle run tests. The physical fitness tests of the female anorexic adolescents showed scores significantly worse than those of the normative European female adolescent population.

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Conclusion

The observation of female adolescents with anorexia nervosa showed associations between higher physical fitness levels and better nutritional statuses. Handgrip strength and 20m shuttle run tests may be options of additional indicators of undernutrition in anorexic female adolescents. The undernourished anorexic patients showed worse physical fitness than the nourished ones. According to normative data for healthy sex- and age-matched adolescents, physical fitness is severely impaired in anorexic female adolescents.

Keywords: Anorexia Nervosa. Exercise test. Female adolescents. Muscle strength. Nutritional status.

RESUMO

Objetivo

Este estudo teve como objetivo determinar se a aptidão física está relacionada ao estado nutricional em uma amostra de adolescentes do sexo feminino com anorexia nervosa, contrastar pacientes nutridas versus desnutridas e comparar a aptidão física nesses pacientes com dados normativos de indivíduos saudáveis estratificados por idade e gênero.

Métodos

O estado nutricional foi determinado pelo escore Z do índice de massa corporal, massa gorda e massa livre de gordura (análise de impedância bioelétrica) e pelo escore do Estado Nutricional Controlador em 15 adolescentes anoréxicas com 14,3±1,6 anos. A aptidão física foi avaliada usando a Bateria ALPHA-Fitness (força de preensão manual, salto em distância em pé, corrida com vaivém 4x10m e corrida com vaivém de 20m).

Resultados

A força de preensão manual foi significativamente associada a todas as variáveis do estado nutricional, exceto aos três componentes sanguíneos do escore do Estado de Controle Nutricional. As pacientes anoréxicas desnutridas mostraram uma aptidão física substancialmente pior do que as pacientes anoréxicas nutridas em todos os testes, exceto nos saltos em pé em posição ampla e nos testes de corrida em 4x10m. Os testes de aptidão física dos adolescentes anoréxicos do sexo feminino apresentaram escores consideravelmente piores do que os da população adolescente europeia normativa.

Conclusão

Adolescentes do sexo feminino com anorexia nervosa apresentaram associação entre maiores níveis de aptidão física e melhor estado nutricional. Os testes de força de preensão manual e corrida de lançadeira de 20m podem ser alternativas como indicadores adicionais do estado de desnutrição em adolescentes anoréxicas. As pacientes anoréxicas desnutridas demonstraram pior condicionamento físico do que as pacientes anoréxicas nutridas. Segundo dados normativos para adolescentes saudáveis de acordo com o sexo e a idade, a aptidão física é gravemente prejudicada em adolescentes anoréxicas do sexo feminino.

Palavras-chave: Anorexia nervosa. Teste de esforço. Adolescentes femininas. Força muscular. Estado nutricional.

INTRODUCTION

Anorexia Nervosa (AN) is a psychiatric disorder characterized by a persistent alteration in the pattern of food intake, an intense fear of weight gain, and a disturbed body image, which in turn produces a physical and psychosocial deterioration [1]. The presence of comorbidity is common, and the prognosis can be negative if it is not diagnosed soon, with high mortality levels [1,2]. Currently, the lifetime prevalence of AN in the general population is estimated to be around 1% in female individuals and it usually appears during adolescence [2]. Anorexia nervosa constitutes a public health problem, as it may result in a prolonged clinical course and tends to become chronic.

Malnutrition, or undernutrition, is defined as a state resulting from the lack of intake or uptake of nutrition that leads to altered body composition (decreased fat free mass) and body cell mass, leading to diminished physical and mental function and impaired clinical outcome [3]. A series

of characteristic physical manifestations appear in AN patients as a consequence of undernutrition [4]. Among the most frequent are a decrease in bone mineral density, weakness of limb musculature, bradycardia, increased aortic stiffness, gastrointestinal symptoms, amenorrhea, syncope, and dizziness [2]. In addition, malnutrition can produce alterations in blood analysis as a decrease in biochemical or hematological nutritional parameters and, for this reason, screening tools have been created for the detection of hospital malnutrition [5-7]. Identifying undernutrition in AN patients is of vital importance in order to apply a refeeding protocol in the shortest time possible and reverse any negative effects [2].

Physical fitness is closely related to adolescent health [8] and decreased risk of chronic disease and premature death [9]. It is important to emphasize that the level of physical fitness in children and adolescents tends to continue into adulthood [10]; therefore, physical fitness is a crucial indicator to evaluate a person's health. Consequently, an evaluation of the level of physical fitness in children and adolescent is of great interest from the perspective of clinical and public health [8].

Anorexia nervosa is a physically debilitating disorder; however, to our knowledge, only one study has evaluated physical fitness in adult female patients with AN before and after weight restoration [11], and no such studies have been conducted on adolescents. There are also no studies that compare the physical fitness of this clinical population with normative data for healthy individuals. Consequently, the objectives of the current study were: (1) to determine whether physical fitness is related to nutritional status in a sample of female adolescents with AN and to contrast the nourished versus undernourished patients; and (2) to compare the physical fitness in these patients with normative data of healthy subjects stratified by age and gender.

METHODS

The Research Ethics Committee of the University Hospital Complex of Huelva approved this study (PI 005/16), (Identifier: NCT03667183) and followed the Declaration of Helsinki, last modified in 2013. An experienced psychiatrist followed the clinical criteria of the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [1] and an endocrinologist was in charge of the evaluation and the medical and nutritional follow-up of the patients. All female patients between 10 and 17 years old with a clinical diagnosis of AN (n=24) from Child-Mental Health Unit of the Vázquez Díaz Hospital (Huelva, Spain) were informed about the study and fifteen subjects agreed to participate. The following inclusion criteria were followed: (1) clinical diagnosis of AN in the aforementioned hospital; (2) aged 10 to 17 years old; (3) approval of the medical team through analytical control and weight stability to perform the tests; and (4) written informed consent by the patients and their legal guardians. The following exclusion criteria were followed: (1) having other diagnoses of mental illness; and (2) consumption of narcotic toxins. All patients were assessed by the same researcher to reduce inter-examiner error.

This observational study was conducted between April 2016 and May 2017. For each participant, a visit was scheduled in which the sociodemographic data, anthropometric data, and blood chemistry work were examined. One week later, the patients underwent physical tests in a specific room conditioned for that purpose. All tests were supervised by qualified health personnel.

We used the InBody 770 (Inbody Co., LTD, Seoul, Korea) to measure weight, fat mass, and fat-free mass through Bioelectrical Impedance Analysis (BIA). In patients with AN, it has been found that multifrequency and octopolar bioelectrical impedance is a method with high reliability

and precision [12], as is the case with InBody 770. This body composition analyzer has already been validated in children and adolescents [13]. A balance with an incorporated stadiometer (Detecto 439; Detecto, USA) was used following standard procedures to measure the height to the nearest 0.1 cm with barefoot subjects. In addition, Tanner stages [14] were used to assess pubertal development in the first assessment. Body Mass Index (BMI) was calculated with the following formula: $\{BMI = \text{Body Mass (kg)} / \text{Height (m)}^2\}$.

After an overnight fasting of at least 9 hours, samples of venous blood were collected. We evaluated two biochemical parameters (serum albumin and total cholesterol) and one immunological parameter (total lymphocyte count) [5]. Serum albumin and total cholesterol were analyzed using the Cobas 8000/C702 analyzer (Roche Diagnostics, Mannheim, Germany), and total lymphocyte count was analyzed using the Sysmex XN modular system (Sysmex, Kobe, Japan).

Physical fitness was evaluated using the extended version of the ALPHA-Fitness Battery (Assessing Levels of Physical Activity and Fitness), which comprises 4 tests [15]. Detailed descriptions of the procedures followed in each test are available elsewhere [14]. In short, two of the tests evaluate muscular fitness, which include handgrip strength for upper body strength and standing broad jump for lower body strength.

The handgrip strength was measured using a hand dynamometer with an adjustable grip (TKK 5101 Grip D; Takey, Tokyo, Japan), and the average of the two hands was calculated.

In the standing long jump test, the participants had to jump as far as possible, pushing off vigorously and landing with their feet together. The total distance was measured from the take-off line to the back of the foot on landing. The 4x10-m shuttle run test was used to evaluate motor fitness. Participants had to run as fast as possible from the start line to the opposite end line, separated by 10 meters, and return. Finally, the 20-m shuttle run test was used to evaluate cardiorespiratory fitness. In this test, the participants had to run a distance of 20m, while keeping pace with a pre-recorded audio CD. The initial speed was 8.5km/h, increased by 0.5km/h per minute. The participants finished the test when they could not follow the audio's reference for the second time, or when the subject stopped due to fatigue. All these tests have shown a close relationship with the current and future health statuses of children and adolescents [15].

Normalized standardized values were calculated $\{Z\text{-score} = [\text{mean-value}] / \text{Standard Deviation [SD]}\}$ for each physical fitness test according to gender and age [16]. In addition, a single muscular fitness Z-score was calculated as the mean of the two standardized scores from the muscular tests (handgrip strength and standing long jump), and the global physical fitness score was calculated as the mean of the four physical fitness Z-scores [17].

There is not only one indicator that can evaluate the nutritional status, so its diagnosis should take several parameters into account [18]. It has been suggested that the Z-score of the BMI is more valid than the BMI in children and adolescents [19,20], and it has been used as a measure in pediatric clinical populations [4]. Carrascosa's, *et al.* reference values [21] were used to transform the BMI into the Z-scores of the BMI according to age and gender. The fat and fat-free mass have been used as measures of body composition in patients with anorexia nervosa [22] since there is a chronic decrease in these patients' body energy reserve [23] due to unusual eating habits, restricted food consumption, and excessive physical activity. Absolute values were used as in previous studies [24,25]. Likewise, we used the Controlling Nutritional Status (CONUT) score, which includes measures of serum albumin, total cholesterol, and total lymphocyte count, and it has demonstrated high sensitivity and specificity (92.3 and 85.0, respectively) as a tool for evaluating nutritional status [5]. Scores of 0 or 1 in the

CONUT are considered normal values and values equal or greater than 2 might be taken as evidence of different levels of undernutrition. Therefore, to discriminate the existence of undernourishment, our subjects should meet at least one of the following criteria: value <-1.00 in BMI Z-score [18,19,26]; value <15 th percentile in the fat and/or fat-free mass corresponding to their gender and age [27]; and/or score ≥ 2 in the CONUT [5].

The Statistical Package for Social Science (SPSS) was used to perform all statistical tests (IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.). Significance was set at $p < 0.05$. The Shapiro-Wilk test was used to assess normality of distribution. The bivariate Spearman's correlation coefficients and linear regression analyses were used to evaluate the associations between the components of nutritional status and the physical fitness Z-scores. A model was created for each variable of the nutritional status, each of them being the dependent variable in each model, and the independent variables were the different physical tests in Z-scores that had significance in the correlation. The U Mann-Whitney test was used to evaluate the significant differences between nourished and undernourished patients. The physical fitness data obtained from the patients was compared with published normative data, where data from thousands of healthy adolescents from ten different European countries has been observed and collected. The normative data of the European adolescent female population [16] was used as a comparison to our sample and to determine possible significant differences. In addition, we calculated the percentile from the individual Z-value of each subject in each variable for which the Z-score was used, and an individual value under the 25th percentile of its gender- and age-matched norm value was defined as clinically different since it is considered low performance [28].

RESULTS

Fourteen of the fifteen subjects in the sample were diagnosed with AN-restricting subtype, and one was atypical AN, according to the DSM-V criteria [1]. The average age was 14.3 (± 1.6) years, height 159.3 (± 7.4) cm, and weight 46.4 (± 8.8) kg. The average Tanner stage was 3.1 (± 0.9). There was no adverse effect after the tests were performed by the participants.

The simple correlation model for adolescent patients with AN revealed significant positive associations between handgrip strength and all variables of nutritional status, except with the three blood components of the CONUT (Table 1). Other significant positive correlations were also found between the fat-free mass with the 20-m shuttle run test, muscular fitness and global physical fitness, and lymphocytes with the 20-m shuttle run test and muscular fitness.

Table 1. Associations between the variables of nutritional status and physical fitness (Z-scores). *Huelva, Spain, 2017.*

Physical fitness	BMI Z-score	Fat mass	Fat-free mass	Albumin	Lymphocyte	Cholesterol
Handgrip strength	0.604*	0.529*	0.879**	-0.089	0.429	-0.170
Standing long jump	0.021	-0.171	0.432	0.213	0.379	0.038
4x10m shuttle run	0.304	0.307	0.396	-0.125	0.104	-0.002
20m shuttle run	0.079	-0.027	0.529*	0.198	0.447*	0.006
Muscular fitness ^a	0.346	0.168	0.700**	0.118	0.475*	-0.050
Global physical fitness ^b	0.364	0.268	0.718**	-0.007	0.407	-0.080

Note: * $p < 0.05$; ** $p < 0.01$; Correlation values are Spearman correlation coefficients; ^aMean of handgrip strength and standing long jump Z-scores;

^bMean of the four physical fitness Z-scores.

In the regression analysis, the independent variable “handgrip strength” explained 73.7% of the variance (R^2) in the model for fat-free mass ($\beta=4.202$, 95% Confidence Interval, 2.697-5.707, $p<0.001$) and it also explained 45.7% of the model for the BMI Z-score ($\beta=0.463$, 95% confidence interval, 0.160-0.765, $p<0.006$).

Undernourishment values (BMI Z-score, fat mass, fat-free mass, and the three blood components of the CONUT) indicated that 60% of the patients were undernourished. The variables of nutritional status and physical fitness used in the study are shown in Table 2. As far as physical fitness is concerned, there were significant differences between the groups in all the variables analyzed except for the standing broad jump and the 4x10-m shuttle run test.

The means of all the obtained scores of the ALPHA-Fitness Battery tests with the female adolescents with AN were significantly worse than the normative European female adolescent population [16] (Table 3). In addition, once we classified each participant according to their age and gender against the European reference values [16], most of the patients were below the 25th percentile in all the fitness tests studied (80% in the 4x10m shuttle run test, 73% in the 20m shuttle run test, 67% in the standing broad jump test, and 53% in the handgrip strength).

Table 2. Characteristics of the study sample by nutritional status. *Huelva, Spain, 2017.*

Variable	Nourished (n=6)	Undernourished (n=9)	<i>p</i>
Age (years)	14.9(1.5)	14.0(1.5)	0.157
Height (cm)	161.9(3.2)	157.5(9.0)	0.443
Weight (kg)	54.0(5.1)	41.4(6.9)	0.007
Nutritional status			
BMI Z-score	-0.2(0.6)	-1.1(0.7)	0.025
Fat mass (kg)	14.8(3.0)	9.6(4.3)	0.034
Fat-free mass (kg)	39.2(3.3)	31.8(4.5)	0.003
Serum Albumin (g/dL)	4.8(0.5)	4.9(0.5)	0.859
Total Lymphocytes/mL	1910.0(340.0)	1930.0(570.0)	0.906
Cholesterol (mg/dL)	174.0(33.8)	178.3(28.9)	0.860
Physical Fitness			
Upper muscular fitness (kg)	27.4(4.3)	19.1(2.4)	0.001
Lower muscular fitness (cm)	123.5(23.1)	108.0(16.5)	0.194
Motor fitness (s) ^a	14.3(1.2)	15.2(1.1)	0.175
Cardiorespiratory fitness (s)	182.7(55.5)	125.2(30.2)	0.045
Muscular fitness (upper+lower muscular fitness; Z-scores)	-0.2(0.9)	-1.3(0.5)	0.010
Global physical fitness (z-scores) ^b	-0.5(0.7)	-1.4(0.5)	0.018

Note: ^aLower values indicate better performance; ^bMean of the four physical fitness Z-scores; Data are shown as the Mean (Standard Deviation), unless otherwise indicated; Nutritional status differences were analyzed by the U Mann-Whitney test, with the variables of nutritional status and physical fitness as dependent variables.

BMI: Body Mass Index.

Table 3. Comparison of physical fitness with normative sample. *Huelva, Spain, 2017.*

Physical fitness	Female adolescents with AN (n=15)	European normative adolescent female sample (n=1845)	<i>p</i>
Handgrip strength (kg)	22.4(5.2)	26.1(4.8)	0.016
Standing long jump (cm)	114.2(20.2)	145.6(26.4)	0.001
4x10m shuttle run (s) ^a	14.8(1.2)	12.8(1.2)	0.001
20m shuttle run (stage)	2.2(0.8)	3.8(1.9)	0.001

Note: ^aLower values indicate better performance; Data are shown as the mean (Standard Deviation), unless otherwise indicated.

DISCUSSION

This study is the first one examining the relation between the nutritional status of female adolescents with AN and their physical fitness. Its main findings highlight that handgrip strength was associated with all variables of nutritional status, except for the three blood components of the CONUT, explaining 74% and 46% in the regression analyzes for fat-free mass and Z-score of the Body Mass Index, respectively. Undernourished female adolescents with AN presented significantly lower upper muscular and cardiorespiratory fitness than did nourished female adolescents with AN. Adolescent patients with AN showed significantly worse physical fitness in all tests compared to that of the healthy female adolescent population matched by age.

Our results indicate that handgrip strength was positively related with three variables of nutritional status such as fat-free mass, fat mass, and BMI Z-score in our adolescent patients with AN. These findings are in line with another study conducted in healthy children and adolescents [29]. A study showed that handgrip strength was positively associated with serum levels of vitamin D [30]. It has also been observed that handgrip strength is a predictive factor for bone density in female adolescents and that having a low level of strength indicates poor health in terms of bone density [31]. It was also reported that the relation between handgrip strength and BMI allowed to discriminate between children with sarcopenic obesity and healthy children [32]. Therefore, our results and other studies suggest that the handgrip strength test can provide important health information about nutritional status in children and adolescent population.

It has been concluded that, among children and adolescents, handgrip strength can better assess malnutrition and it may be a potential marker of undernutrition in hospitalized patients [26]. Adolescent girls with low weight obtained lower levels of handgrip strength compared to girls with normal weights [33]; however, other studies found no differences in handgrip strength among female adolescents with low weight or normal weight, as well as those who are overweight [34]. This may be because low weights in this population do not necessarily mean that they suffer from undernutrition. Handgrip strength has been shown to be a functional method of nutritional assessment [35] and it might predict malnutrition in patients with Crohn's disease [36].

A high level of handgrip strength is strongly associated with better cardiovascular health [37]. The well-known strong positive correlations between fat-free mass and cardiorespiratory fitness [38] was also found in our results; however, we observed a moderate correlation between lymphocytes with cardiorespiratory fitness and muscle fitness. The muscular function responds more quickly to nutritional deprivation and nutritional repletion than the parameters of corporal composition such as muscle or corporal mass [39,40]; for this reason, it must be evaluated in patients with greater risks of undernutrition. Laboratory values are mostly delayed and costly, and largely dependent on the analytic method and the analyzing laboratory [40]. However, handgrip strength and 20m shuttle run tests are simple and non-invasive markers, which make them suitable for daily clinical practice, especially as they are easy to measure and very cost-effective [41,42]. Many hospitals and health care centers have spacious rooms where the 20-m shuttle run test could be performed, while the handgrip strength test would only require a dynamometer. In addition, these tests are quick to perform, even as they always require medical supervision. Therefore, the assessment of physical fitness, especially upper muscular fitness and cardiorespiratory fitness, seems to be a practical, simple, easily accessible, and low-cost alternative as additional indicators of undernutrition in female adolescents with AN, and thus are preferable in comparison with more expensive and complex methods.

Undernourished anorexic patients showed worse nutritional status levels than the nourished anorexic patients in all variables, except for the blood components of the CONUT. This seems to be in line with Gómez-Candela *et al.* [43], that states that biological data in patients with AN are usually within the limits of normality, except when there are further complications. Undernourished anorexic patients showed worse physical fitness levels than nourished anorexic patients, except in the lower muscular and motor fitness. This finding is in agreement with a study in adults which reported that handgrip strength could differentiate between well-nourished and malnourished hospitalized patients and change with nutritional status [44].

By comparing each of the four physical tests of our sample of adolescents with AN and the European normative adolescent female population [16], we found that our patients were significantly worse in terms of all of the variables. Muscular fitness has been evaluated in adult female anorexic patients [11] and the values obtained were similar to those of our sample, but we must consider the age difference between the samples; thus, they should be compared with caution. A previous study concluded that muscular fitness is associated with a better state of physical health and that adolescents with better muscular performance have lower scores on the cardiovascular risk components [45]. Low levels of physical fitness in young people with a normal BMI but a high percentage of body fat seem to be partially mediated by lower skeletal muscle mass [46]. In addition, participation in organized sport is associated with greater physical fitness and better body composition among adolescents (lower BMI and body fat percentage) [47]. Likewise, we classified each patient according to age and gender in the European reference values, and we found that the majority of the patients were below the 25th percentile in all physical fitness tests. This is probably due to the consequent physiological deterioration of anorexia nervosa, with reduced muscle mass, bone mass, and connective mass when compared to the general population, which is reflected in physical fitness. Our results show that our AN population has worse physical fitness than healthy individuals of their age with an objectively measured physical disability. Thus, anorexia nervosa in female adolescents might be conceived as a physically debilitating disorder.

The current study has some limitations. First, the cross-sectional design means we cannot make cause-effect inferences. Second, there are known limitations of all nonprobability samples, such as their lower representativeness and unknown levels of sampling errors. Third, the relatively small size of our sample also limits its statistical power and the validity of the resulting data; however, as anorexia nervosa is an illness with low prevalence, it is difficult to get a large number of affected adolescents enrolled and to obtain the permission of their legal guardians. By its design, the present study does not include a prospective control group with which the data on nutritional status and physical fitness could be compared. To eliminate any selection bias, we chose to use normative data representative of larger population groups. Therefore, the references used are more representative of the population that does not suffer from eating disorders than if we had evaluated 15 adolescents who do not have this illness. This is the first preliminary study analyzing physical fitness levels in adolescents with AN. Future research initiatives should include a larger sample of adolescents with AN and perform the assessment of other anthropometric variables such as the forearm circumference. As a strength, however, our study measured all values of body and blood composition and physical fitness objectively.

CONCLUSION

Female adolescents with anorexia nervosa showed associations between higher physical fitness levels and better nutritional status. Handgrip strength and 20m shuttle run tests may be additional indicators of the state of undernutrition in anorexic female adolescents. The undernourished anorexic

patients showed worse physical fitness than the nourished ones. According to normative data for healthy sex- and age-matched adolescents, physical fitness is severely impaired in anorexic female adolescents.

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CONTRIBUTIONS

SM MARTÍNEZ-SÁNCHEZ conceived and designed the research, conducted the experiments, analyzed and interpreted the data, wrote the manuscript and revised. TE MARTÍNEZ-GARCÍA conceived and designed the research, analyzed and interpreted the data, and revised. D MUNGUÍA-IZQUIERDO conceived and designed the research, conducted the experiments, analyzed and interpreted the data and revised. All authors read and approved the final manuscript.

REFERENCES

1. American Psychiatric Association. DSM-5. Manual Diagnóstico y Estadístico de los Trastornos Mentales. 5th ed. Madrid: Editorial Médica Panamericana; 2014.
2. Zipfel S, Giel KE, Bulik CM, Hay P, Schmidt U. Anorexia nervosa: aetiology, assessment, and treatment. *Lancet Psychiat*. 2015;2(12):1099-111. [http://dx.doi.org/10.1016/S2215-0366\(15\)00356-9](http://dx.doi.org/10.1016/S2215-0366(15)00356-9)
3. Cederholm T, Barazzoni R, Austin P, Ballmer P, Biolo G, Bischoff SC, *et al*. ESPEN guidelines on definitions and terminology of clinical nutrition. *Clin Nutr*. 2017;36(1):49-64. <http://dx.doi.org/10.1016/j.clnu.2016.09.004>
4. Murphy AJ, Hill RJ, Buntain H, White M, Brookes D, Davies PSW. Nutritional status of children with clinical conditions. *Clin Nutr*. 2017;36(3):788-92. <http://dx.doi.org/10.1016/j.clnu.2016.05.014>
5. Ignacio de Ulíbarri J, González-Madroño A, Villar NGP, González P, González B, Mancha A, *et al*. CONUT: a tool for controlling nutritional status: first validation in a hospital population. *Nutr Hosp*. 2005;20(1):38-45.
6. Zhang Y, Zhang X. Controlling nutritional status score, a promising prognostic marker in patients with gastrointestinal cancers after surgery: a systematic review and meta-analysis. *Int J Surg*. 2018;55:39-45. <http://dx.doi.org/10.1016/j.ijso.2018.05.018>
7. Molina Soria JB, Lobo Támer G, Pérez de la Cruz AJ, Ruiz-López MD. Prevalence of malnutrition to income in a basic general hospital. *Nutr Hosp*. 2017;34(5):1390-8. <http://dx.doi.org/10.20960/nh.1133>
8. Júdice PB, Silva AM, Berria J, Petroski EL, Ekelund U, Sardinha LB. Sedentary patterns, physical activity and health-related physical fitness in youth: a cross-sectional study. *Int J Behav Nutr Phys Act*. 2017;14(1):25. <http://dx.doi.org/10.1186/s12966-017-0481-3>
9. Castro-Piñero J, Perez-Bey A, Segura-Jiménez V, Aparicio VA, Gómez-Martínez S, Izquierdo-Gomez R, *et al*. Cardiorespiratory fitness cutoff points for early detection of present and future cardiovascular risk in children: a 2-year follow-up study. *Mayo Clin Proc*. 2017;92(12):1753-62. <http://dx.doi.org/10.1016/j.mayocp.2017.09.003>
10. Palakshappa D, Virudachalam S, Oreskovic NM, Goodman E. Adolescent physical education class participation as a predictor for adult physical activity. *Child Obes*. 2015;11(5):616-23. <http://dx.doi.org/10.1089/chi.2015.0024>
11. Alberti M, Galvani C, Capelli C, Lanza M, El Ghoch M, Calugi S, *et al*. Physical fitness before and after weight restoration in anorexia nervosa. *J Sports Med Phys Fitness*. 2013 [cited 2020 Apr 8];53(4):396-402. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/23828287>
12. Li Q, Li X, Leng Y, Zhu X, Yao G. [Assessing nutritional status of severe malnutrition patients by bioelectrical impedance technique: a multicenter prospective study]. *Zhonghua Wei Zhong Bing Ji Jiu Yi Xue*. 2018;30(2):181-4. <http://dx.doi.org/10.3760/cma.j.issn.2095-4352.2018.02.017>

13. Ohta M, Midorikawa T, Hikiyama Y, Masuo Y, Sakamoto S, Torii S, *et al.* Validity of segmental bioelectrical impedance analysis for estimating fat-free mass in children including overweight individuals. *Appl Physiol Nutr Metab.* 2017;42(2):157-65. <http://dx.doi.org/10.1139/apnm-2016-0137>
14. ALPHA study Group. The ALPHA health-related fitness test battery for children and adolescents: test manual. Granada: Granada University; 2011 [cited 2020 Apr 8]. Available from: <http://www.ugr.es/~cts262/ES/documents/ALPHA-FitnessTestManualforChildren-Adolescents.pdf>
15. Ruiz JR, Castro-Pinero J, Espana-Romero V, Artero EG, Ortega FB, Cuenca MM, *et al.* Field-based fitness assessment in young people: the ALPHA health-related fitness test battery for children and adolescents. *Br J Sports Med.* 2011;45(6):518-24. <http://dx.doi.org/10.1136/bjsm.2010.075341>
16. Ortega FB, Artero EG, Ruiz JR, Espana-Romero V, Jimenez-Pavon D, Vicente-Rodriguez G, *et al.* Physical fitness levels among European adolescents: the HELENA study. *Br J Sports Med.* 2011;45(1):20-9. <http://dx.doi.org/10.1136/bjsm.2009.062679>
17. Segura-Jiménez V, Parrilla-Moreno F, Fernández-Santos JR, Esteban-Cornejo I, Gómez-Martínez S, Martínez-Gómez D, *et al.* Physical fitness as a mediator between objectively measured physical activity and clustered metabolic syndrome in children and adolescents: the UP&DOWN study. *Nutr Metab Cardiovasc Dis.* 2016;26(11):1011-9. <http://dx.doi.org/10.1016/j.numecd.2016.07.001>
18. Bouma S. Diagnosing pediatric malnutrition: paradigm shifts of etiology-related definitions and appraisal of the indicators. *Nutr Clin Pract.* 2017;32(1):52-67. <http://dx.doi.org/10.1177/0884533616671861>
19. Golden NH, Katzman DK, Sawyer SM, Ornstein RM. Position paper of the society for adolescent health and medicine: medical management of restrictive eating disorders in adolescents and young adults references. *J Adolesc Heal.* 2015;56(1):121-5. <http://dx.doi.org/10.1016/j.jadohealth.2014.10.259>
20. Freedman DS, Lawman HG, Skinner AC, McGuire LC, Allison DB, Ogden CL. Validity of the WHO cutoffs for biologically implausible values of weight, height, and BMI in children and adolescents in NHANES from 1999 through 2012. *Am J Clin Nutr.* 2015;102(5):1000-6. <http://dx.doi.org/10.3945/ajcn.115.115576>
21. Carrascosa Lezcano A, Fernández García JM, Fernández Ramos C, Ferrández Longás A, López-Siguero JP, Sánchez González E, *et al.* [Spanish cross-sectional growth study 2008: part II: height, weight and body mass index values from birth to adulthood]. *An Pediatr (Barc).* 2008;68(6):552-69. <http://dx.doi.org/10.1157/13123287>
22. Achamrah N, Coeffier M, Dechelotte P. Physical activity in patients with anorexia nervosa. *Nutr Rev.* 2016;74(5):301-11. <http://dx.doi.org/10.1093/nutrit/nuw001>
23. Koletzko B. 3.22 Nutrition rehabilitation in eating disorders. *World Rev Nutr Diet.* 2015;113:259-65. <http://dx.doi.org/10.1159/000375192>
24. Achamrah N, Colange G, Delay J, Rimbart A, Folope V, Petit A, *et al.* Comparison of body composition assessment by DXA and BIA according to the body mass index: a retrospective study on 3655 measures. *Plos One.* 2018;13(7):e0200465. <http://dx.doi.org/10.1371/journal.pone.0200465>
25. Agüera Z, Romero X, Arcelus J, Sánchez I, Riesco N, Jiménez-Murcia S, *et al.* Changes in body composition in anorexia nervosa: predictors of recovery and treatment outcome. *Plos One.* 2015;10(11):e0143012. <http://dx.doi.org/10.1371/journal.pone.0143012>
26. Jensen KC, Bellini SG, Derrick JW, Fullmer S, Eggett D. Handgrip strength and malnutrition (undernutrition) in hospitalized versus nonhospitalized children aged 6-14 years. *Nutr Clin Pract.* 2017;32(5):687-93. <http://dx.doi.org/10.1177/0884533617698098>
27. Mei Z, Grummer-Strawn LM, Pietrobelli A, Goulding A, Goran MI, Dietz WH. Validity of body mass index compared with other body-composition screening indexes for the assessment of body fatness in children and adolescents. *Am J Clin Nutr.* 2002;75(6):978-85. <http://dx.doi.org/10.1093/ajcn/75.6.978>
28. Mandsager K, Harb S, Cremer P, Phelan D, Nissen SE, Jaber W. Association of cardiorespiratory fitness with long-term mortality among adults undergoing exercise treadmill testing. *JAMA Netw Open.* 2018;1(6):e183605. <http://dx.doi.org/10.1001/jamanetworkopen.2018.3605>
29. Musa TH, Li W, Xiaoshan L, Guo Y, Wenjuan Y, Xuan Y, *et al.* Association of normative values of grip strength with anthropometric variables among students, in Jiangsu Province. *HOMO.* 2018;69(1-2):70-6. <http://dx.doi.org/10.1016/j.jchb.2018.03.007>
30. Wakayo T, Belachew T, Whiting SJ. Serum vitamin D level associates with handgrip muscle strength among ethiopian schoolchildren: a cross-sectional study. *Food Nutr Bull.* 2018;39(1):54-64. <http://dx.doi.org/10.1177/0379572117724545>

31. Forero-Bogota MA, Ojeda-Pardo ML, Garcia-Hermoso A, Correa-Bautista JE, Gonzalez-Jimenez E, Schmidt-RioValle J, *et al.* Body composition, nutritional profile and muscular fitness affect bone health in a sample of school children from Colombia: the Fuprecol study. *Nutrients*. 2017;9(2):106. <http://dx.doi.org/10.3390/nu9020106>
32. Steffl M, Chrudimsky J, Tufano JJ. Using relative handgrip strength to identify children at risk of sarcopenic obesity. *Plos One*. 2017;12(5):e0177006. <http://dx.doi.org/10.1371/journal.pone.0177006>
33. Dong B, Wang Z, Arnold L, Song Y, Wang HJ, Ma J. The association between blood pressure and grip strength in adolescents: does body mass index matter? *Hypertens Res*. 2016;39(12):919-25. <http://dx.doi.org/10.1038/hr.2016.84>
34. Lad UP, Satyanarayana P, Shisode-Lad S, Siri CC, Ratna Kumari N. A study on the correlation between the Body Mass Index (BMI), the body fat percentage, the handgrip strength and the handgrip endurance in underweight, normal weight and overweight adolescents. *J Clin Diagnostic Res*. 2013;7(1):51-4. <http://dx.doi.org/10.7860/JCDR/2012/5026.2668>
35. Zhang XS, Liu YH, Zhang Y, Xu Q, Yu XM, Yang XY, *et al.* Handgrip strength as a predictor of nutritional status in Chinese elderly inpatients at hospital admission. *Biomed Environ Sci*. 2017;30(11):802-10. <http://dx.doi.org/10.3967/bes2017.108>
36. Lu ZL, Wang TR, Qiao YQ, Zheng Q, Sun Y, Lu JT, *et al.* Handgrip strength index predicts nutritional status as a complement to body mass index in crohn's disease. *J Crohn's Colitis*. 2016;10(12):1395-400. <http://dx.doi.org/10.1093/ecco-jcc/jjw121>
37. Ramírez-Vélez R, Tordecilla-Sanders A, Correa-Bautista JE, Peterson MD, Garcia-Hermoso A. Handgrip strength and ideal cardiovascular health among Colombian children and adolescents. *J Pediatr*. 2016;179:82-89.e1. <http://dx.doi.org/10.1016/j.jpeds.2016.08.099>
38. Köhler A, King R, Bahls M, Groß S, Steveling A, Gärtner S, *et al.* Cardiopulmonary fitness is strongly associated with body cell mass and fat-free mass: the Study of Health in Pomerania (SHIP). *Scand J Med Sci Sport*. 2018;28(6):1628-35. <http://dx.doi.org/10.1111/sms.13057>
39. Gregorio L, Brindisi J, Kleppinger A, Sullivan R, Mangano KM, Bihuniak JD, *et al.* Adequate dietary protein is associated with better physical performance among post-menopausal women 60-90 years. *J Nutr Health Aging*. 2014;18(2):155-60. <http://dx.doi.org/10.1007/s12603-013-0391-2>
40. Reber E, Gomes F, Vasiloglou MF, Schuetz P, Stanga Z. Nutritional risk screening and assessment. *J Clin Med*. 2019;8(7):1065. <http://dx.doi.org/10.3390/jcm8071065>
41. Smelt HJM, Pouwels S, Celik A, Gupta A, Smulders JF. Assessment of physical fitness after bariatric surgery and its association with protein intake and type of cholecalciferol supplementation. *Medicina (Kaunas)*. 2019;55(6):281. <http://dx.doi.org/10.3390/medicina55060281>
42. Tomkinson GR, Lang JJ, Blanchard J, Léger LA, Tremblay MS. The 20-m Shuttle run: assessment and interpretation of data in relation to youth aerobic fitness and health. *Pediatr Exerc Sci*. 2019;31(2):152-63. <http://dx.doi.org/10.1123/pes.2018-0179>
43. Gómez-Candela C, Palma Milla S, Miján-de-la-Torre A, Rodríguez Ortega P, Matía Martín P, Loria Kohen V, *et al.* Consenso sobre la evaluación y el tratamiento nutricional de los trastornos de la conducta alimentaria: anorexia nerviosa. *Nutr Hosp*. 2018;35(Spec No1):11-48. <http://dx.doi.org/10.20960/nh.1562>
44. Flood A, Chung A, Parker H, Kearns V, O'Sullivan TA. The use of hand grip strength as a predictor of nutrition status in hospital patients. *Clin Nutr*. 2014 Feb;33(1):106-14. <http://dx.doi.org/10.1016/j.clnu.2013.03.003>
45. Rodriguez Valero FJ, Alberto Gualteros J, Andres Torres J, Umbarila Espinosa LM, Ramirez-Velez R. Association between muscular fitness and physical health status among children and adolescents from Bogota, Colombia. *Nutr Hosp*. 2015;32(4):1559-66. <http://dx.doi.org/10.3305/nh.2015.32.4.9310>
46. Zhang M, Schumann M, Huang T, Törmäkangas T, Cheng S. Normal weight obesity and physical fitness in Chinese university students: an overlooked association. *BMC Public Health*. 2018;18(1):1334. <http://dx.doi.org/10.1186/s12889-018-6238-3>
47. Agata K, Monyeki MA. Association between sport participation, body composition, physical fitness, and social correlates among adolescents: the PAHL Study. *Int J Environ Res Public Health*. 2018;15(12):2793. <http://dx.doi.org/10.3390/ijerph15122793>

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