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Body fat, but not muscle quality, is related to perceived fatigue in young-adult active and inactive women

Gordura corporal, mas não a qualidade muscular, é relacionada a fadiga percebida em mulheres adultas jovens ativas e inativas

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Abstract – The purpose of this study was to investigate the association of perceived fatigue with body composition and muscle quality (strength, thickness and specific torque) in young adult women. Fifty-one healthy women (31.98 ± 6.88 years) were assessed regarding perceived fatigue, body composition, knee extensors muscle strength, muscle thickness, and muscle quality. The short version of International Physical Activity Questionnaire was applied to classify subjects as active or inactive. To examine the relationship between perceived fatigue and dependent variables, the Pearson's correlation was performed. Perceived fatigue was significantly correlated ($p < 0.05$) with body weight ($r = 0.469$), body mass index ($r = 0.369$), fat mass ($r = 0.469$), percent body fat ($r = 0.396$), and relative peak torque ($r = -0.378$). Additionally, inactive women had significantly greater ($p < 0.05$) body weight, body mass index, fat mass, percent body fat, and perceived fatigue than active women. Perceived fatigue is related to body weight and fat mass, but not to muscle strength or muscle quality. Moreover, physically active women showed lower perceived fatigue, body weight, and body fat compared to physically inactive women. These results suggest that body fat may play a role in perceived fatigue and physical activity could attenuate such symptom.

Key words: Adiposity; Fatigue; Mental fatigue; Muscle strength; Physical activity.

Resumo – *O objetivo deste estudo foi investigar a associação da fadiga percebida com a composição corporal e a qualidade muscular (força, espessura e torque específico) em mulheres adultas jovens. Cinquenta e uma mulheres foram avaliadas quanto a fadiga percebida, a composição corporal, a força muscular de extensão de joelho, a espessura muscular e a qualidade muscular. A versão curta do Questionário Internacional de Atividade Física foi aplicada para classificar as voluntárias como ativas ou inativas.Para examinar a relação entre a fadiga percebida e as variáveis dependentes, a correlação de Pearson foi executada. A fadiga percebida apresentou relação significativa ($p < 0,05$) com o peso corporal ($r = 0,469$), IMC ($r = 0,369$), massa gorda ($r = 0,469$), percentual de gordura ($r = 0,396$) e pico de torque relativo ($r = -0,378$). Adicionalmente, mulheres inativas apresentaram maior ($p < 0,05$) peso corporal, índice de massa corporal, massa gorda, percentual de gordura e fadiga percebida, comparadas com mulheres ativas. A fadiga percebida se relaciona com o peso corporal e com a gordura corporal, mas não com a força muscular ou com a qualidade muscular. Além disso, mulheres fisicamente ativas tem uma menor fadiga percebida, peso corporal e gordura corporal do que mulheres fisicamente inativas. Esses resultados sugerem que a gordura corporal exerce um papel importante na fadiga percebida e que a atividade física pode atenuar esse sintoma.*

Palavras-chave: *Adiposidade; Atividade física; Fadiga; Fadiga mental; Força muscular.*

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INTRODUCTION

Fatigue is a multifactorial syndrome that promotes many disabling and impairing dysfunctions[1]. This syndrome was initially distinguished as central and peripheral fatigue. Currently, as exposed by Enoka et al.[2], fatigue is identified and recognized as two interdependent attributes:performance fatigability and perceived fatigability.Although both elements show substantial interactions, they are related to distinct modulating factors. Performance fatigability depends on contractile function and muscle activation. Otherwise, perceived fatigability is the change in sensations that regulate the integrity of the performer based on the maintenance of homeostasis and the psychological state of the individual, and depends on neurotransmitters, metabolites, oxygenation, pain, wakefulness, and energeticbalance[2].

Several studies have already described an increased perceived fatigue in cancer[3], chronic fatigue syndrome[4], and multiple sclerosis[5]. The increase of perceived fatigue is related to some physiological dysfunctions in unhealthy populations[3,5,6]. An overstated release of pro-inflammatory cytokines and an amplified production of reactive oxygen species (ROS) may play a role in perceived fatigue[6]. In addition, ROS could damage mitochondria and induce metabolic dysfunction. Also, both inflammatory and metabolic imbalance may affect the hypothalamic-pituitary-adrenal axis and the availability of serotonin, dopamine, norepinephrine, and cortisol[3].

Nevertheless, few studies have investigated the relationship between perceived fatigue and physical function in healthy population. Silva et al.[7] showed a strong relationship between strength, physical activity and perceived fatigue in elderly women. In consequence, an increased perceived fatigue in older individuals may lead to a functional dependence, a decreased health-related quality of life, and an increased morbidity and mortality rate[8]. Considering that aging process induces several physiological changes, such as inflammatory imbalance and mitochondrial dysfunction, the relationship between perceived fatigue and aging is quite expected[9].

Regarding healthy young subjects, Vantieghem et al.[10] showed that perceived fatigue is related to body fat, physical activity and physical performance in healthy adolescents aged between 12 and 20 years. The association between body fat and perceived fatigue could be speculatively explained by physiological changes induced in overweigh conditions. The accumulation of adipose tissue induces an inflammatory imbalance that leads to a decrease of mitochondrial biogenesis and metabolic function[11]. Since mitochondria control energy production and metabolic pathways, dysfunctions in these organelles could affect physiological environment, increase ROS production and rise inflammation[12]. Thereby, it is plausible to speculate that an accumulation of adipose tissue may induce a higher perceived fatigue.

Physical activity is markedly a relevant strategy to improve physical function in unhealthy subjects[13]. However, considering that health status, gender and physical fitness could affect independently perceived fatigue, the relationship between physical outcomes and perceived fatigue in young adult women is still unknown. Thus, the purpose of this study was to investigate the association of perceived fatigue with body composition and muscle quality (strength, thickness and specific torque) in young adult women. It was hypothesized that perceived fatigue would be positively associated with body fat, body mass index, fat mass and percent body fat; and negatively associated with muscle quality.

METHOD

Subjects

This cross-sectional study included healthy, non-pregnant, women aged between 20 and 45 years recruited from university community, by word of mouth, and advertisements on the internet. The volunteers were excluded if they had cardiovascular, respiratory, muscular, metabolic or neuroendocrine disorders. They were also excluded if they had been consuming alcohol, creatine, beta-alanine, caffeine, ephedrine, ornithine, branched chain amino acids, carnitine, leucine or its metabolites, arginine, tryptophan, and/or antioxidants in the previous 30 days before enrollment in the study. Additionally, participants were excluded if they had used anabolic steroids or hormonal precursors in the previous year before the study protocol. After applying the exclusion criteria, 51 women were included in this study. In order to classify subjects as active or inactive, the short version of International Physical Activity Questionnaire (IPAQ) was applied. This questionnaire classifies physical activity in four levels, as follow: 1) inactive, 2) insufficiently active, 3) active and 4) very active. The participants were considered inactive when classified in the first or second levels, and active when classified in the third or fourth levels. All participants were fully informed of the purpose, procedures, and possible risks related to the study, and provided a written informed consent. The study was approved by the University Institutional Ethics Committee and was conducted in accordance with ethical standards.

Experimental procedures

The enrolled participants attended to the laboratories at University of Brasília once. The subjects were submitted to the following tests and evaluations: 1) physical activity level and perceived fatigue assessment;2) anthropometry and body composition measurements; and 3) muscle thickness, strength and quality assessment.All participants were asked to follow pre-assessment guidelines before reporting to the laboratory, including discontinuing physical exertion for at least 24 hours prior to the evaluations.All measurements and protocols were conducted in the morning to avoid circadian variations, and were conducted by the same researcher, in a controlled-temperature room, during approximately 60 minutes. Over the study protocol volunteers were instructed to maintain their usual dietary intake

Perceived fatigue

Self-perceived fatigue was measured through the Multidimensional Fatigue Inventory (MFI-20). This questionnaire was designed to assess perceived fatigue levels among different subjects, groups and/or conditions, and are applied to a varied population[14]. Five dimensions comprise the questionnaire, which measure fatigue experienced in previous days: general fatigue, physical fatigue, reduced activity, reduced motivation, and mental fatigue. To evaluate the relationship between perceived fatigue and physical function, only General Fatigue was used as a wide, global, and general perceivedfatigue indicator. The score was calculated in a range of 4 to 20 points, with 4 being little perceived fatigue and 20 the highest level of perceived fatigue.

Anthropometry and body composition

Standard procedures were used to measure weight with 0.1 kg precision on a physician's digital balance beam scale (model E150-INAN Filizola, São Paulo, Brazil), and height was measured at the nearest 0.1 cm with a wall stadiometer (WCS/ CARDIOMED, Curitiba, Brazil). Body mass index (BMI) was derived as body weight divided by height squared (kg/m^2). Fat mass, fat free mass and percent body fat were measured by dual-energy X-ray absorptiometry – DXA (General Electric-GE model 8548 BX1L, 2005, DPX lunar type, Encore 2010 software, Rommelsdorf, Germany). Coefficients of variation observed for DXA in our laboratory were 2.1 % and 1.9 % for fat mass and fat free mass, respectively. All measurements were carried out by the same trained technician and the equipment was daily calibrated according to the manufacturers' specifications.

Muscle thickness, strength, and quality

Knee extensors muscles thickness (MT) was measured using a B-mode ultrasound (Philips, VMI, Lagoa Santa, Brazil). The measurement of MT was taken at 60% of the distance from the greater trochanter to the lateral epicondyle and 3 cm lateral to the midline of the anterior thigh[15]. Once the examiner found a satisfactory image, it was frozenon the monitor, stored and analyzed in software Image-J (National Institute of Health, USA, version 1.49). The distance between subcutaneous adipose tissue-rectus femoris interface and vastus intermedius-bone interface was designated as knee extensors muscle thickness. All measurements and analyses were performed three times by the same researcher and the mean value was considered for analysis. A 7.5-MHz scanning probe was placed on the skin perpendicular to the tissue interface. The scanning probe was coated with a water-soluble transmission gel to provide acoustic contact without depressing the dermal surface. No additional pressure was applied to standardize the compression on the dermal surface. The ultrasound intra-rater reliability was 0.94 and the coefficient of variation was 2.4%.

Isokinetic muscle strength (peak torque [PT] and relative peak torque [RPT]) was measured using an isokinetic dynamometer Biodex System 3

(Biodex Medical Systems, Inc., New York, USA). Subjects were positioned on the dynamometer seat with safety belts fastened to the trunk, pelvis and thigh to avoid extraneous body movements that could affect PT values. The lateral epicondyle of the femur was used to align the knee rotation axis and the dynamometer rotation axis, allowing free knee extension and flexion from 85º flexion up to full extension. Gravity correction was obtained by measuring the torque exerted by the lever arm and the subject's leg at 30º flexion as well as in a relaxed position. The values of the isokinetic variables were automatically adjusted for gravity with the software Biodex Advantage (Biodex Medical Systems, Inc., New York, USA). The calibration of the dynamometer was carried out according to the specifications provided by the manufacture. For the test, volunteers were asked to cross their arms across the chest. The same researcher carried out the test procedures for all subjects and provided verbal encouragement. As part of familiarization with isokinetic knee extension and warm-up, subjects performed one set of 10 submaximal knee isokinetic extension at 120º.s-1. Five minutes after familiarization/warm-up session, volunteers performed two sets of four maximal isokinetic knee extension at 60º/s-1[16]. The volunteers rested three minutes between both sets. Test-retest reliability coefficient (ICC) value for knee extensor peak torque was 0.91 in our laboratory.

Muscle quality was assessed by specific torque (ST). The ST was defined as the force produced per unit of muscle tissue (i.e., muscle thickness). The ST was calculated as follows: isokinetic peak torque / MT[17].

Statistical analysis

Data are presented as mean and standard deviation. Normal distribution parameters were checked with Shapiro-Wilk test.To compare perceived fatigue and physical outcomes between active and inactive women, independent samples t-test were conducted. Cohen's d was calculated to estimate the magnitude of the difference according the following criteria: < 0.20 small; 0.20 – 0.50 medium; 0.80 – 2.00 large. To assess the relationship between perceived fatigue and independent variables, the Pearson's correlation coefficient was calculated. The correlation was classified according the following criteria: 0.0 – 0.4 (positive or negative) weak; 0.4 – 0.7 (positive or negative) moderate; 0.7 – 1.0 (positive or negative) strong. Statistical significance was set at $p \leq 0.05$. All statistical analyses were conducted with Statistical Package for Social Sciences software version 21.0 (SPSS Inc., Chicago, United States of America).

RESULTS

Fifth-one healthy young adult women were assessed. The descriptive characteristics, body composition, ST and perceived fatigue for the whole sample and according to physical activity status are reported in table 1. Thirty volunteers (59%) were identified as physically active and twenty-one (41%) as physically inactive. There were no between-group differences for age, height, fat free mass and knee extensors muscle thickness and peak torque. However, inactive women showedgreater body weight (p= 0.045, ES= 0.564), body mass index (p= 0.050, ES= 0.541), fat mass (p= 0.004, ES= 0.825, figure 1), percent body fat (p= 0.002, ES= 1.136) and general fatigue (p= 0.019, ES= 0.702)compared to their physically active counterparts; moreover, inactive women also showed lower specific torque (p= 0.041, ES= 0.625).

The relationships between perceived fatigue and physical outcomes are exposed in table 2. Perceived fatigue was significantly related to age, body weight, height, body mass index, fat mass, fat free mass, percent body fat, and relative peak torque. Otherwise, perceived fatigue was not significantly related to fat free mass, peak torque, muscle thickness and specific torque.

Table 1. Descriptive characteristics, body composition, muscle quality and perceived fatigue of active and inactive young adult women. Data are presented as mean (standard deviation) and effect size.

Variable	Total (n= 51)	Active (n= 30)	Inactive (n= 21)
Age (years)	31.98 (6.88)	31.77 (6.62)	32.27 (7.39)
Bodyweight (kg)	63.42 (10.77)	60.90 (8.52)	67.01 (12.72)*
Height (m)	1.62 (0.06)	1.62 (0.06)	1.63 (0.04)
Body mass index (kg.m^{-2})	24.06 (3.85)	23.18 (2.69)	25.31 (4.87)*
Fat mass (kg)	23.88 (8.53)	21.10 (6.58)	27.86 (9.53)*
Fat freemass (kg)	36.34 (3.94)	36.85 (4.10)	35.62 (3.68)
PercentBodyfat (%)	38.76 (7.88)	36.00 (7.06)	42.70 (4.43)*
Peak Torque (N.m)	153.25 (26.32)	154.30 (29.33)	151.74 (21.91)
RelativePeak Torque (%)	246.93 (47.31)	256.35 (48.13)	233.47 (43.74)
Musclethickness (mm)	25.33 (6.29)	24.34 (6.70)	26.75 (5.51)
Specific torque (N.m.mm^{-1})	6.27 (1.31)	6.59 (1.41)	5.82 (1.02)*
Perceived fatigue	11.63 (3.79)	10.60 (3.84)	13.10 (3.25)*

Note.*Significant difference from active group (p< 0.05).

Table 2. Pearson's correlations between perceived fatigue, age, body composition and muscle quality in young adult women.

Variable	Perceived fatigue	
	r	p
Age (years)	0.337	0.016
Bodyweight (kg)	0.438	0.001
Height (m)	0.322	0.021
Body mass index (kg.m^{-2})	0.331	0.018
Fat mass (kg)	0.469	0.001
Fat freemass (kg)	0.166	0.246
PercentBodyfat (%)	0.419	0.002
Peak Torque (N.m)	-0.104	0.466
RelativePeak Torque (%)	-0.426	0.002
Musclethickness (mm)	0.044	0.761
Specific torque (N.m.mm^{-1})	0.014	0.923

DISCUSSION

Several studies have already assessed the perceived fatigue in unhealthy and healthy subjects. However, modulating factors could differ between different conditions and populations. The present study was designed to investigate the association between perceived fatigue and physical outcomes, such as body fat, muscle strength and muscle quality, in young adult women. As hypothesized, perceived fatigue was positively related to body weight, fat mass and percent body fat. However, in contrast to our hypothesis, no negative associations were observed between perceived fatigue, muscle strength, thickness and quality.

The relationship between body fat and perceived fatigue, in a speculative view, may be related to physiological and biochemical changes induced by adipose tissue accumulation. Adipose tissue produces cytokines that induce inflammatory and metabolic impairments[18,19]. Also, fat tissue may increase ROS release, which contributes to mitochondrial dysfunction and metabolic syndrome[18]. Thus, both inflammatory imbalance and oxidative stress are related to an increased perceived fatigue in unhealthy populations[20]. Additionally, body fat may impact physical function and promote physical inactivity, developing a circle of obesity, sedentary lifestyle and an increased perceived fatigue[21]. These thoughts could be supported by the differences in perceived fatigue and fat mass between active and inactive women.

An interesting data of this study was the divergence between the body fat indexes. The participants could be classified by BMI as normal weight or overweight. However, they showed an increased percentage of body fat[22], showing propensity for obesity. Although the women were aged under 45 years, the substantial amount of adipose tissue combined with a loss of muscle mass could denote a sarcopenic obesity[23]. Such condition is related to an increased inflammation[19], and may increase perceived fatigue. However, this relationship between inflammation and perceived fatigue is still speculative and must be confirmed in healthy young adult women.

Nevertheless, perceived fatigue was not related to muscle strength, thickness or quality. This finding does not agree with previous studies. Moratalla-Cecilia et al.[24]suggested that physical fitness is directly and consistently associated with physical dimension of quality of life in adult women aged between 40 to 65 years. Similarly, Vantieghem et al.[10]showed that high-fatigued adolescents had lower muscle strength and endurance than low-fatigued adolescents. However, these studies have assessed subjects with a different age-range compared to the present study. Therefore, it is possible to speculate that physical fitness affect perceived fatigue differently depends on the age.

In the present study, it was also observed that perceived fatigue was related to age. The relationship between perceived fatigue and age has already been reported previously in elderly[9]. Such relationship may be linked to multiple biological and psychological changes associated with aging (i.e. changes in body composition, increases in inflammatory markers, and impairments in metabolic function)[9]. In fact, inflammatory imbalance induced by aging plays an important role in muscle weakness, oxidative stress, and perceived fatigue[25]. Although previous studies have already reported a relationship between perceived fatigue and aging, it was done in elderly patients[9]. The current study shows a positive and significant relationship between perceived fatigue and age, even in a sample composed by young adult women, aged between 20 and 45 years.

The practice of any physical activity seems to affect consistently perceived fatigue[26].In this study, the inactive women were suffering a substantial perceived fatigue, while active women were suffering, on average, a reduced fatigue. According Singer et al [27], women younger than 39 years old show a substantial perceived fatigue if the score reported on MFI-20 is greater than 11.0.Physical exercise may reduce weight and body fat, improve functional capacity and decrease inflammation[28], leading to an improvement in perceived fatigue.According to American College of Sports Medicine, physical activity plays an important role in weight management, with strong evidences that could both prevent weight gains and promotes weight loss. Also, physical activity contributes to adipose tissue gains prevention even without caloric restriction[29]. This effect may be attributed to different modalities of physical exercise, such as aerobic and strength training[29]. Furthermore, exercise training contributes to attenuate inflammatory imbalance and oxidative stress induced by body fat[30].

Although the results of the present study support the association between physical activity and perceived fatigue, the method used to classify active and inactive women should be seen carefully. The use of questionnaires to assess physical activity does not identify exercise modality or training aspects, and could be influenced by personal tendencies. However, it is important to note that the simply practice of physical activity, regarding modality, seems to improve perceived fatigue.

The current study has several strength and limitations.An important limitation of this cross-sectional study was the relatively small sample size. However, this study should be seen as a hypothesis-generating study, providing information about perceived fatigue. Additionally, menstrual cycle and food intake were not controlled prior to testing. For future research, it is recommended that other fatigue assessments and larger sample size should be used. Despite the non-assessment of biological markers of oxidative stress and inflammation, it is also important to note that this study provides insight on the potential effects of physical activity on perceived fatigue due to physical and physiological changes.

CONCLUSION

In summary, perceived fatigue is related to body fat, body mass index and body weight, but not to muscle strength, thickness, and quality. It is plausible to speculate that physiological and functional changes induced by adipose tissue contribute to increase perceived fatigue in young adult women. Additionally, physically active women showed lower perceived fatigue, body weight, body mass index, fat mass and percent body fat, and a greater specific torque than inactive women.

COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee – University of Brasília (CAAE: 36741914.4.0000.0030) and the protocol was written in accordance with the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

AUTHOR CONTRIBUTIONS

Conceived and designed the experiments: FDL, ROV and ALMC. Performed the experiments: FDL, SGRN, ALMC and ROV. Analyzed the data: FDL and RML. Contributed with reagents/materials/analysis tools: FDL, RML and MB. Wrote the paper: FDL, SGRN, RML and MB.

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