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Comparison between two motor tests used for muscular strength/endurance analysis in young women

Comparação entre dois testes motores utilizados para análise da força/resistência muscular em mulheres jovens

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Abstract – The aim of this study was to compare motor performance in modified pull-up (MPU) and flexed knee push-up (FKPU) tests in young women. Thirty-five apparently healthy women (20.1±2.2 years) were submitted to each one of the tests at an interval of 48 hours in a random balanced design. Most individuals performed between 0 and 10 repetitions (86%) of the MPU test, and approximately 17% did not perform even one repetitions. On the other hand, the highest prevalence of outcomes for the FKPU test was between 16 and 35 repetitions (71%). The Wilcoxon test identified statistically significant differences ($p < 0.01$) on motor performance in the tests analyzed (FKPU > MPU). A moderate agreement ($\kappa = 0.40$) was found between the performance in both tests. Negative correlations of low magnitude ($r = -0.23$ to 0.46) were found between morphological variables (body weight, height, fat mass, and lean body mass) and motor performance in both tests. The results suggest that the FKPU test is presented as a better indicator of muscular endurance levels, whereas the MPU test seems to better discriminate muscular strength in young women.

Key words: Evaluation; Exercise test; Physical exercise; Physical exertion; Physical fitness.

Resumo – O objetivo deste estudo foi comparar o desempenho motor nos testes de flexão e extensão dos braços em suspensão na barra modificada (FEBbarra) e flexão e extensão de braços, no solo, com apoio dos joelhos (FEBlivre) em mulheres jovens. Trinta e cinco mulheres aparentemente saudáveis (20,1 ± 2,2 anos) foram submetidas a cada um dos testes, em um intervalo de 48 h, de forma aleatória e balanceada. No teste FEBbarra, a maioria dos indivíduos executou entre 0 e 10 repetições (86%), sendo que, aproximadamente, 17% não executaram sequer uma repetição. Por outro lado, no teste FEBlivre a maior prevalência de resultados foi entre 16 e 35 repetições (71%). O teste de Wilcoxon identificou diferenças estatisticamente significativas ($P < 0,01$) no desempenho motor nos testes analisados (FEBlivre > FEBbarra). Uma concordância moderada ($\kappa = 0,40$) foi encontrada entre o desempenho nos dois testes. Correlações negativas e de fraca magnitude ($r = -0,23-0,46$) foram verificadas entre variáveis morfológicas (massa corporal, estatura, massa gorda e massa corporal magra) e o desempenho motor em ambos os testes. Os resultados sugerem que o teste FEBlivre se apresenta como um melhor indicador dos níveis de resistência muscular, enquanto que o teste FEBbarra parece discriminar melhor a força muscular em mulheres jovens.

Palavras-chave: Aptidão física; Avaliação; Esforço físico; Exercício físico; Teste de esforço.

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INTRODUCTION

Muscular strength and endurance are considered physical capacity constraints, fundamental to the practice of most sports, physical exercise programs of different types, as well as to perform various daily activities. Thus, the development and/or maintenance of adequate levels of muscular strength/endurance can help prevent postural problems, fractures, musculoskeletal injuries, osteoporosis, decreased incidence of falls, in addition to promoting joint stability^{1,2}. Additionally, individuals who have reduced muscular strength with increasing age generally have a higher risk for all causes of mortality³.

Considering the importance and influence of muscular strength/endurance in different contexts, several methods have been used to evaluate these physical capabilities such as hand grip test, dynamometry, and field tests⁴⁻⁶. Therefore, several field tests have been developed and recommended by leading international organizations in an attempt to offer relatively simple alternatives with good accuracy, low operating costs, and wide application in different professional environments (gyms, clubs, clinics, among other locations) and for research, particularly in studies involving a large number of subjects⁷.

If on the one hand the Canadian Fitness Survey, the YMCA, the American College of Sports Medicine (ACMS), and Cooper Institute for Aerobic Research recommend the flexed knee push-up (FKPU) test to assess muscular strength/endurance of the upper limbs in women; on the other hand the American Alliance for Health, Physical Education, Recreation, and Dance (AAHPERD) and the President's Council on Physical Fitness and Sports recommend, for the same purpose, the modified pull-up (MPU) test⁷. It is worth noting, however, that the decision making process for choosing one of these two tests to evaluate muscular strength/endurance should not be done indiscriminately since the muscle groups required and the level of muscle activation during the execution of each of these are not similar, which can lead to different responses depending on the specific characteristics of the person being evaluated (level of physical fitness, experience in performing similar tasks, level of trainability of muscle groups required, body size).

Although researchers report high levels of reliable ($r=0.71$ to 0.95), when the criteria of standardization established are carefully followed⁸, little is known about the power of discrimination of the results produced by the FKPU and MPU tests for analyzing muscular strength/endurance. This information could assist greatly in the decision making process for choosing these tests to assess muscular strength/endurance, especially in women since they in general have absolute muscle strength, body mass, and muscle mass very different from men, which could limit the application of some motor tests or generate measurements with a low power of discrimination in this population.

Thus, the aim of this study was to analyze comparatively the motor performance of young women in FKPU and MPU field tests. Addition-

ally, the level of agreement between the scores produced by the two tests was investigated along with the possible associations between each one of them with anthropometric variables and body composition indicators. Whereas these tests are quite popular and frequently used for similar purposes (assessment of muscular strength/endurance), our hypothesis is that both tests have a good power of discrimination of the results, a good agreement between each other, and that some morphological variables can discriminate, at least in part, the physical performance in these motor tasks.

METHODS

Subjects

Thirty-five apparently healthy untrained women (20.1 ± 2.2 years) participated voluntarily in this study. All participants signed the terms of informed consent after they had been previously clarified about the study's proposal and the procedures to which they would be submitted. This study is part of a broader research project of a longitudinal character that investigated the effect of weight training and creatine supplementation on several parameters in young adults. The study was conducted in accordance with the instructions contained in Resolution 196/96 of the National Health Council for studies involving human beings from the Ministry of Health and approved by the Research Ethics Committee of the State University of Londrina (case no. 028/2012).

Anthropometry

Body mass was obtained using scales of the brand Urano, model PS 180A accurate to 0.1kg, and height was determined using a wooden stadiometer, accurate to 0.1cm, according to the procedures described in literature⁹. All participants were measured and weighed barefoot. The body mass index (BMI) was calculated from these measurements by dividing body weight/height² with the body mass being expressed in kilograms (kg) and height in meters (m).

Body composition was determined by the technique of skinfold thickness. Three measurements were taken at each anatomical point (suprailiac, subscapular, triceps, and calf) in rotational sequence on the right hemisphere, and the median value was recorded. These measurements were taken by a single measurer with a Lange scientific caliper according to internationally standardized techniques¹⁰. The test-retest coefficient exceeded 0.95 for each one of the anatomical points with a technical error of measurement of at the most 5%.

Relative body fat was calculated using Siri's formula¹¹ based on the estimation of body density determined by the equation of four skinfolds proposed for women by Petroski¹².

Motor tests

The assessment of muscular strength/endurance of the upper limbs was performed by applying the MPU¹³ and FKPU¹⁴ tests. In order to carry out the

FKPU test, each participant was placed in the prone position with knees and hands resting on the floor with an aperture of 10 to 20cm from the shoulder line (outer side) with the fingers pointing forward. The positioning of the hands on the floor was maintained at the height of the shoulders. During the execution of a sequence, it was required that the participants at the eccentric phase of the movement, lower their body until the chest reached the elbow line (approximately 90° of elbow flexion) and from there the full extension of the elbows was carried out in the concentric phase. Regarding the MPU test, the participants were placed under the bar in the supine position with arms fully extended (elbows extended) with the shoulders aligned with the bar, body erect, and only the heels in contact with the floor. The hands were placed in a pronated grip at a distance according to the width of the shoulders. During the concentric phase of the test, it was required that the participants elevate their body by flexing their elbows until the throat area touched the demarcation line placed two spaces below the bar. Next, the participants had to return to the starting position with elbows extended. The total number of completed repetitions was recorded for each of the two tests as long as properly executed in a single trial without a time limit and without stopping between repetitions¹⁵. It is worth noting that no specific execution cadence was required. The two tests were done in a random balanced way (cross-over) with a 48-hour interval between them.

Statistical analysis

The Shapiro-Wilk test was used to analyze the data distribution. Since the FKPU test data presented a Gaussian distribution and the MPU test data presented a non-Gaussian distribution, these variables were described in median amounts and interquartile intervals. The Wilcoxon test was used for comparisons between the scores obtained in these two tests. The other variables were normally distributed and therefore were represented in the average values, standard deviation, and confidence interval of 95%. We used the Kappa index (data categorized into tertiles) from the cutoff points suggested by Svanholm et al.¹⁶ in order to analyze the agreement between the scores produced by the two tests. A simple correlation analysis was used to analyze possible associations between morphological variables and the performance on the FKPU and MPU tests. The significance level adopted for all analyses was $p < 0.05$. The data was processed using the software SPSS 17.0. Based on the average variation of the performance observed in the two tests, it was determined that 28 subjects would be needed to achieve a statistical power of 80% with an alpha of 95%.

RESULTS

The physical characteristics of the 35 participants of this study are presented in average, standard deviation (SD), and confidence interval of 95% (CI95%) in Table 1.

Table 1. Physical characteristics of participants (n=35)

Variables	Average	SD	CI95%
Age (years)	20.1	2.2	19.3-20.8
Body mass (kg)	55.5	6.1	53.4-57.6
Height (cm)	163.1	6.3	160.9-165.3
BMI (kg/m ²)	20.8	1.6	20.3-21.4
% Fat	22.8	3.9	21.4-24.1
FM (kg)	12.8	3.1	11.7-13.8
LBM (kg)	42.7	4.1	41.3-44.2

SD = standard deviation; CI95% = confidence interval of 95%; BMI = body mass index; FM = fat mass, LBM = lean body mass.

Figures 1 and 2 present the individual results obtained in the MPU and FKPU tests respectively. Most of the women performed between 0 and 10 repetitions (85.7%) of the MPU test, and 17.1% did not perform even one repetition. On the FKPU test, however, the results indicated a predominance of scores in the range between 16 and 35 sequences (71%). It is worth noting that in this test, all the volunteers were able to complete at least one repetition.

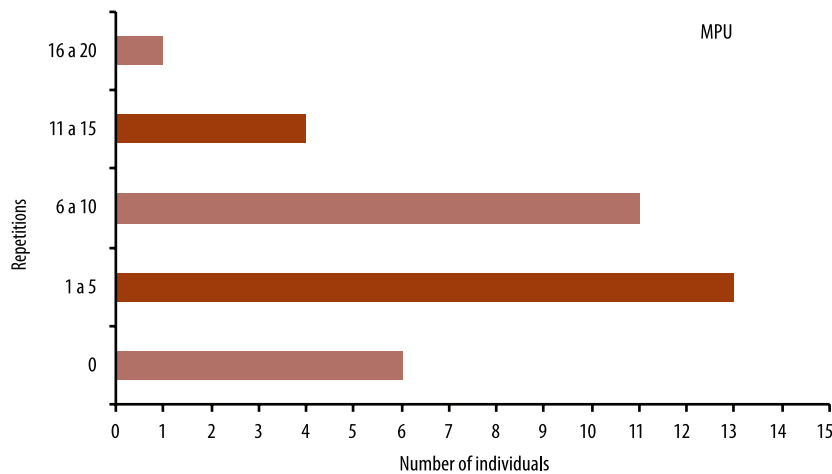


Figure 1. Distribution of the sample according to the motor performance for the MPU test (n=35).

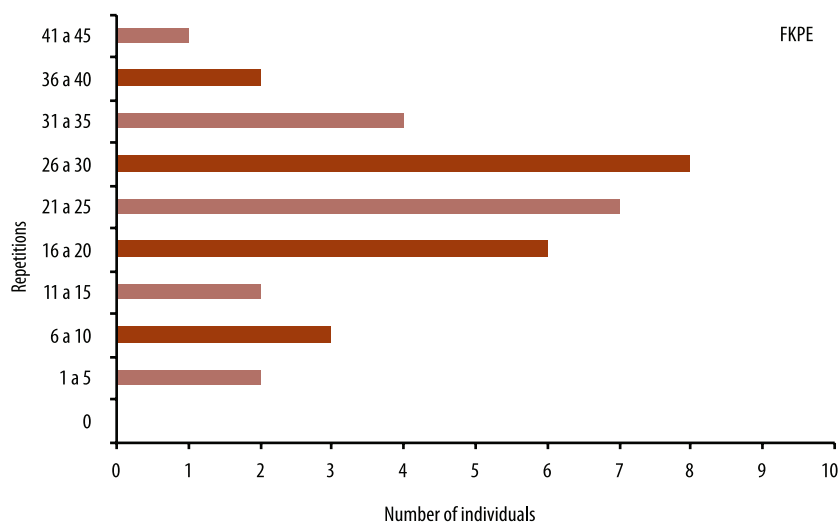


Figure 2. Distribution of the sample according to the motor performance for the FKPU test (n=35).

The comparison between the scores on the FKPU and MPU tests is presented in Figure 3. The motor performance analysis of the group analyzed indicated statistically significant differences between the scores obtained in the two tests with the highest levels being identified in the FKPU test ($p < 0.001$).

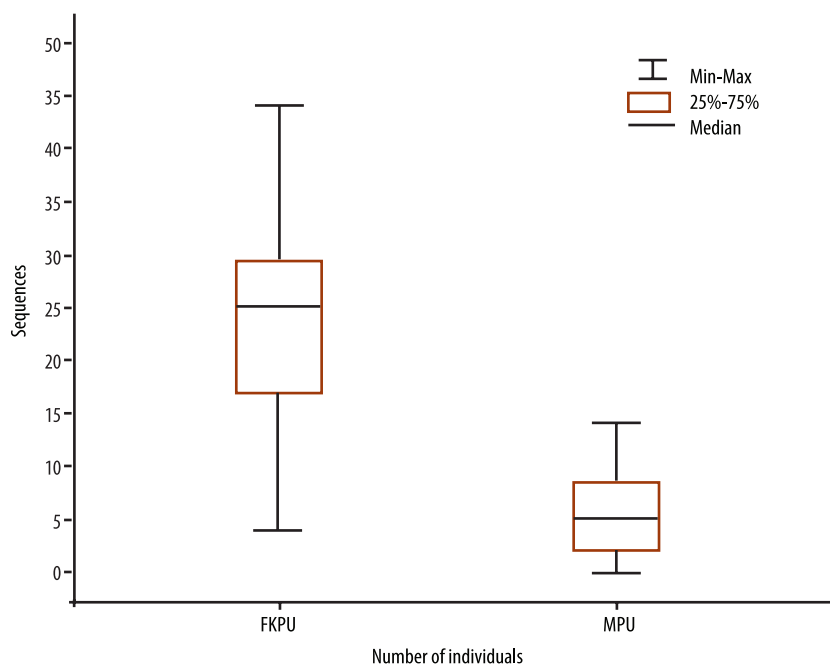


Figure 3. Descriptive values of the scores obtained by women in the FKPU and MPU tests ($n=35$). $*p < 0.05$

The correlation coefficients between each test and the morphologic variables studied are presented in Table 2. Negative correlations of low magnitude ($r = -0.23$ to 0.46) were found between body weight, height, fat mass, and lean body mass) and the FKPU and MPU tests.

Table 2. Simple correlation coefficients between morphological variables and performance on the MPU and FKPU tests ($n=35$)

Variables	MPU		FKPU	
	r	p	r	p
Body mass (kg)	-0.37	0.03	-0.32	0.06
Height (cm)	-0.37	0.03	-0.46	<0.01
FM (kg)	-0.34	0.04	-0.32	0.06
LBM (kg)	-0.25	0.14	-0.23	0.18

FM = fat mass; LBM =lean body mass

A positive and moderate significant correlation ($r=0.658$; $p < 0.01$) and a moderate agreement (Kappa = 0.40 ; $p < 0.01$) were identified between the scores obtained in the FKPU and MPU tests.

DISCUSSION

The results of this study indicated a moderate association between MPU

and FKPU tests with the number of repetitions reached in the MPU test being much lower than that found in the FKPU test. Additionally, the two tests showed a moderate agreement between themselves and moderate to weak correlations were identified between the morphological variables analyzed and the performance observed in each test. Furthermore, the ability to discriminate the performance in the tests investigated was greater in the FKPU test considering that the number of zero results observed in the MPU test did not make it possible to make a more consistent analysis of muscular strength/endurance based on the scores obtained in this test at approximately 1/5 of the sample.

It is believed that the high amount of scores equal to or greater than 15 in the FKPU test and equal to or less than five in the MPU test identified in this study can be explained, at least in part, by the different muscle groups involved in the concentric phase of the movement and by the overload imposed for sustaining the body, as required in each task. Despite the absence in this study of muscle activation measurements, previous studies that used EMG indicated that the main muscles activated during the MPU test are the infraspinatus, teres major, upper portion of the pectoralis major, biceps brachii, and latissimus dorsi¹⁷, while the triceps brachii, pectoralis major, serratus anterior, and posterior deltoid muscles are the ones more activated during the FKPU test¹⁸. Therefore, considering that the capacity to generate force of the elbow flexor muscles, especially the biceps brachii, is less than the elbow extensors, a greater degree of difficulty was already expected in performing the MPU test when compared to FKPU test, which was confirmed by the results found in this study.

Therefore, although muscle strength and endurance are physical capabilities that hold important relationships among themselves, to the point that most motor test batteries opt to use the joint designation between muscular endurance and strength^{13,14} to designate a particular test, the application of the FKPU and MPU tests, indiscriminately, may hinder a more consistent analysis of these physical abilities in various subjects. Accordingly, based on the distribution of the scores obtained in the two tests investigated in this study (Figures 1 and 2), it can be seen that the FKPU test presented scores of different magnitudes and with a higher amplitude. On the other hand, on the MPU test, part of the sample investigated (17.1%) was unable to perform even one repetition, which hampered the analysis of both the muscular strength and endurance of these women. Furthermore, the level of agreement between the tests was only moderate, suggesting that the categorization of the subjects based on the levels of muscular strength/endurance is test-dependent in most cases, which in itself can lead to significant interpretation errors (underestimation or overestimation of muscular strength/endurance) when these tests are applied indiscriminately.

Despite that the possible influence of body mass and other morphologic variables on physical performance has been the subject of previous investigations in both anaerobic^{19,20} and aerobic^{21,22} activities, as well as in the comparison between genders²³, the results reached so far are still in-

conclusive since the magnitude of the contribution of these variables seems to depend on the characteristics of the motor task required. In this study it was believed that the motor performance in each test could be largely explained by the morphological variables, which was not confirmed, mainly in relation to body mass, fat mass, and lean body mass in the FKPU test. The only morphological variable investigated that presented an inverse and significant correlation with motor performance in both tests was height. Thus, height seems to be a relevant factor in motor performance in both tests analyzed, with the shorter subjects presenting a tendency to better motor performance in both tests, which seems to be related to the shorter articular distance to be reached during the execution of each sequence, resulting consequently in a lower total energy expenditure. Relatively similar results to ours were reported by Mayhew et al.²⁴ when analyzing the performance with push-ups of male college students.

More recently, other factors have been investigated in an attempt to explain the motor performance on specific tests such as genetic polymorphism and chromosomal regions simultaneously related^{25,26}. This information, though preliminary, is very promising and deserves to be analyzed more consistently in further investigations since they were not analyzed in this study.

It is important to point out that neural adaptations such as increased recruitment of high-threshold motor units, improved synchronization of the antagonistic muscle groups, increasing the frequency of stimulation, and improving the synchronization of the stimulated motor units can distinguish the behavior of the subjects in motor tests depending on the individual fitness level (sedentary, physically active, or athletes), experience before the exercise (inexperienced, with a little experience, or experienced), and type of exercise (mono-articular or multi-articular)²⁷. Therefore, it should be considered that the lack of familiarization sessions before the two tests analyzed may have influenced motor performance, especially in the MPU test since an important part of the sample investigated was unable to perform even one single movement.

In this sense, some investigations based on the 1-RM test for assessing muscular strength have demonstrated the importance of conducting test familiarization sessions prior to the actual assessments themselves in order to produce more consistent scores by reducing the possible effects of learning the motor gesture^{27,28}. However, we found no information available in the literature on the possible effect of familiarization sessions prior to the two tests analyzed in similar samples, which limits a more careful analysis of the possible limitations brought about by the lack of familiarization on the results.

Although the physical fitness level of the participants was not controlled, the crossover design adopted in this study allows us to believe that the differences in strength levels between the participants did not compromise the analysis since the sample investigated was subjected to both tests with the order of execution being controlled. However, one

cannot disregard the possible intra-individual effect of the differences in muscular strength/endurance of the muscle groups required in each test and its impact on the categorization generated from the performance observed. In short, care must be taken with respect to the analysis of the results produced by the MPU and FKPU tests since the fragility of some muscle groups in comparison to others can result in a highly heterogeneous physical performance and may compromise the diagnosis of muscular strength/endurance and prescription of exercises.

Finally, despite the great interest of the scientific community in offering alternatives that are relatively simple, of low cost, of large application in different professional environments and research involving a large number of subjects, the indiscriminate application of the MPU and FKPU tests needs to be reconsidered. Based on the results found in this investigation, the FKPU test does not seem to discriminate the levels of muscular strength, being apparently more useful for assessing muscular endurance, confirming previously published information²⁴. Furthermore, although some researchers have used the MPU test to evaluate muscular endurance^{29,30}, the results of this study indicate that this test, at least in young women, does not seem to discriminate muscular endurance for most of those evaluated and presents limitations for categorizing the levels of muscle strength, particularly in subjects who cannot complete even one repetition.

CONCLUSIONS

The results of this study indicate that the FKPU and MPU tests should not be applied indiscriminately to assess muscular strength/endurance in young women since the level of agreement between them is only moderate and the physical demands are relatively distinct. The amplitude analysis of the scores achieved in each test and the level of discrimination of the results in the sample investigated suggest that the FKPU test presents itself as a better indicator of the levels of muscular endurance, while the MPU test seems to discriminate better muscular strength in young women.

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