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# Functional capacity assessment of upper limbs in healthy young adult subjects

## *Avaliação da capacidade funcional de membros superiores em indivíduos adultos jovens saudáveis*

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### Abstract

**Introduction**: Assessing the functional capacity of the upper limbs (UL) is essential to direct treatments in clinical practice but there is a lack of research on specific methods for this end. **Objective**: To verify the relationship of physical activity, grip strength (GS) and body mass index (BMI) with performance on 6-minute Pegboard and Ring Test (6PBRT) in healthy subjects. **Methods**: Cross-sectional, exploratory and quantitative study. Apparently healthy adults were evaluated, both sexes, according to sociodemographic and anthropometric aspects, health conditions, physical activity level (IPAQ - short version), GS and functional capacity of the upper limbs (6PBRT). The data were analyzed descriptively using means, standard deviations, absolute figures and percentages. Correlations were found between variables using Spearman's correlation coefficient ($p < 0.05$). The Statistical Package for Social Sciences (SPSS) for Windows, version 17.0 was used for analysis purposes. **Results***:* In total, 50 individuals were evaluated, the majority classified as active (54%). The mean GS was 30.70 ± 9,47kgf and the average number of loops moved during the 6PBRT was 277.6 ± 34.48. There was no correlation between the number of rings moved in 6PBRT and the level of physical activity ($r = 0.076$; $p = 0.602$), GS ($r = -0.008$; $p = 0.956$) or BMI ($r = 0.031$; $p = 0.829$). **Conclusion**: The level of physical activity, GS and BMI did not influence the performance on 6PBRT, demonstrated by the lack of correlation between these variables.

**Keywords:** Assessment. Upper Extremity. Muscle Strength. Motor Activity. Healthy Volunteers.

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*Resumo*

***Introdução:*** *A avaliação da capacidade funcional de membros superiores (MMSS) é fundamental para o direcionamento de tratamentos na prática clínica, porém apresenta escassez de pesquisas que abordem métodos específicos para tal objetivo.* ***Objetivo****: Verificar a relação do nível de atividade física (NAF), da força de preensão palmar (FPP) e do índice de massa corporal (IMC) com o desempenho no 6-minute Pegboard and Ring Test (6PBRT) em indivíduos saudáveis.* ***Métodos****: Estudo descritivo, transversal, analítico e quantitativo. Foram avaliados indivíduos adultos saudáveis, ambos os gêneros, segundo aspectos sociodemográficos, condições de saúde, antropométricos, NAF (IPAQ – versão curta), FPP e capacidade funcional de MMSS (6PBRT). Os dados foram analisados descritivamente por meio de médias, desvios padrão, números absolutos e porcentagens e foram verificadas as correlações entre as variáveis pelo coeficiente de correlação de Spearman (p < 0,05).* ***Resultados****: Totalizaram 50 indivíduos avaliados, sendo a maioria classificados como ativos (54%). A média da FPP foi de 30,70 ± 9,47kgf e a média do número de argolas movidas durante o PBRT foi de 277,6 ± 34,48. Não houve correlação entre o número de argolas movidas no PBRT com o NAF (r = 0,076; p = 0,602), com a FPP (r = -0,008; p = 0,956) e nem com o IMC (r = 0,031; p = 0,829).* ***Conclusão:*** *O NAF, a FPP e o IMC não influenciaram no desempenho do 6PBRT, demonstrado pela ausência de correlação entre essas variáveis.*

***Palavras-chave:*** *Avaliação. Extremidade Superior. Força Muscular. Atividade Motora. Voluntários Saudáveis.*

## Introduction

The functional capacity of the upper limbs (UL) is an important component in the execution of activities of daily living (ADLs), as their integrity permits the appropriate performance of the UL functions, which are guided reaching, grip and object handling (1).

Nevertheless, some chronic respiratory diseases can cause a loss in UL functioning, like chronic obstructive pulmonary disease (COPD), cystic fibrosis and idiopathic pulmonary fibrosis. In these cases, the overall functional capacity is reduced (2 - 4) and the performance of ADLs may even be affected (3 - 6). Individuals with severe COPD frequently report difficulties to perform activities using UL, mainly when they need to be sustained (7). One of the factors impairing these activities is dyspnea (8), which can be related to significant ventilation and metabolic changes as well as pulmonary hyperinsuflation (9, 10).

During the execution of ADLs, some muscles responsible for arm positioning, that is, muscles with postural functions, can also be recruited to perform the accessory ventilator function. Hence, individuals with respiratory dysfunctions, especially in case of chronic respiratory diseases, can present changes in UL functioning as, in view of the activities of the UL, the muscles in the upper part of the trunk cease to act only for ventilation purposes. As a result, the diaphragm is increasingly active, causing symptoms that can limit certain UL activities, the most common being dyspnea (8). The limitations on physical exercise worsen, due to the abnormal abdominal-thoracic movement these patients present, in view of the physical effort and mechanical disadvantage that increases the respiratory work (11).

When lifting the arms, oxygen consumption increases by approximately 16%, as well as pulmonary ventilation, increasing by about 24% in healthy individuals. These factors can modify the mechanics of the rib cage and abdominal compartment, resulting in thoracoabdominal dyssynchrony (8). In addition, studies suggest that the impact of UL activity on the respiratory pattern adopted and on the pulmonary mechanics can interfere in the imposed demand and the consequent limitation to exercise (12).

In addition, due to these changes, the individuals affected by chronic respiratory diseases present a trend to reduce their physical exercise due to the symptoms they present and become more sedentary (13), a fact that will influence the reduction of their peripheral muscle strength (14). Hence, the lesser the level of physical exercise, the greater the losses in peripheral muscle strength and, consequently, these factors can influence the functional capacity negatively (15).

Thus, UL training has been recommended by guidelines as part of pulmonary rehabilitation programs, because it enhances the functional capacity of the UL and reduces the ventilation and oxygen consumption while exercising these body parts (16, 17).

As important as achieving the desired benefits of UL training is functional capacity assessment, in order to help and determine the appropriate protocol to allow each individual to achieve these results. Nevertheless, specific recommendations on how to objectively measure the UL exercise capacity in individuals with chronic respiratory conditions remain scarce (18).

Few UL functional capacity assessment methods have been described, like the arm ergometer, which is considered the gold standard to assess UL endurance. Through this equipment, the maximum cardiorespiratory responses can be determined. Disadvantages include its high cost, the need for periodical maintenance, besides the different UL positioning during the test (with support and shoulders at 90º) from what is adopted during ADLs (19). On the other hand, Celli, Rassulo and Make developed another form of UL assessment in 1986 (20), validated by Zanh et al. in 2006 (21), called the 6-minute Pegboard and Ring Test (6PBRT). The objective of this test is also to assess the functional capacity of the UL. Its advantages are its easy and fast application, taking only six minutes, besides its low cost, facilitating health professionals' access to apply and collect the test in clinical practices. In addition, the 6PBRT represents the ADLs more similarly as, during the test, the UL are placed without support, simulating the position adopted while executing ADLs.

Therefore, UL functional capacity assessment through this method can serve as a relevant tool for clinical practice. In addition, there is a lack of studies using the 6PBRT in different populations, especially in healthy individuals, for the sake of comparison with individuals suffering from chronic respiratory conditions. Thus, the primary objective in this study was to verify the relation between the level of physical activity, grip strength (GS) and body mass index (BMI) and performance on the 6PBRT in healthy individuals. The secondary objectives were to identify the physiological changes occurred and the feeling of dyspnea and UL fatigue reported during and after the 6PBRT.

## Methods

### Study design

A descriptive, cross-sectional and analytic quantitative study was undertaken.

### Population

Fifty healthy individuals were assessed aged 18 years or older, male and female. This study was forwarded to the institutional Ethics Committee for Research involving Human Beings (CEP) and approved under opinion 356.214 / 2013.

All individuals were informed about the study objectives and method and agreed to participate by signing the informed consent form, in compliance with National Health Council Resolution 466 from December 12th 2012.

### Inclusion criteria

Male and female apparently healthy individuals aged 18 years or older were included in the study.

### Exclusion criteria

Individuals were excluded from the study when unable to answer the questionnaire or engage in the physical tests; suffering from chronic respiratory, neuromuscular, metabolic or cardiovascular diseases; suffering from bone, muscle, joint, orthopedic problems and neurological sequelae that prevented them from performing the proposed tests. These alterations were previously identified using a semistructured questionnaire, applied to characterize the sample.

### Place of data collections

The assessments took place at the Laboratory for Spirometry and Respiratory Physiotherapy of Universidade Federal de São Carlos (UFSCar), located in the city of São Carlos - São Paulo, Brazil.

### Assessment measures

Sample

The individuals were interviewed individually, when a semistructured questionnaire was applied, including questions on sociodemographic data (e.g.: gender, age) and clinical data (referred diseases).

### Physical Assessment

- Anthropometric assessment

The anthropometric data and BMI were assessed using calibrated anthropometric scales (Filizola®), with the individual barefoot and wearing as little clothing as possible (22). The body mass was obtained in kilos (Kg) and the height in meters (m). To calculate the BMI, the body mass was divided by the squared height (Kg/m$^2$).

- Functional capacity assessment of upper limbs

The functional capacity of the upper limbs was assessed using the 6PBRT.

- 6-minute Pegboard and Ring Test (6PBRT)

The 6PBRT was developed by Celli et al. (20) and validated by Zhan et al. (21) in individuals suffering from COPD, when the test was applied to assess the functional capacity of the upper limbs. It is a UL exercise test in which the upper limbs are not sustained and no load is used.

The test was performed by means of a square with four pins. The two inferior pins were placed at the height of the volunteer's shoulders and the two upper pins 20 cm higher (Figure 1). Ten rings were placed on the inferior pins (weighing approximately 14.17 grams each). The volunteers sat down on a chair, using the back rest and their feet resting on the floor, facing the square and were instructed to move one ring at a time, using both hands, from the inferior to the superior pin, starting with the volunteer's dominant side. When all rings had been changed from the inferior to the superior level, they were returned to the inferior level and the same procedure was repeated on the opposite side. This rotation was maintained successively for six minutes (23).

Source: Property of the authors.

**Figure 1** - Pegboard equipment.

The moving of the rings was self-paced, that is, the volunteer freely determined the rhythm and was allowed to rest during the test if he felt that was necessary, in order to return if wanted, while the chronometer was running. Blood pressure (BP), heart rate (HR), peripheral oxygen saturation (SpO2) were verified at the start and end of the test. To perceive the UL fatigue and dyspnea at the start and end, the BORG (24) scale was used.

The total score was calculated by the amount of rings moved during six minutes, representing the test performance.

- Peripheral muscle strength assessment

The peripheral muscle strength was measured based on the grip strength, assessed using a manual hydraulic JAMAR dynamometer (model SAEHAN® Hydraulic Hand Dynamometer, Masan 630-728 KOREA). Some studies have demonstrated that this is a fast and effective method to measure the global muscle strength. In addition, significant correlations are found between this and other functional capacity and limb strength tests (25 - 27).

The GS was measured according to the recommendations of the American Society of Hand Therapists (ASHT), in which individuals sat down without arm support, feet resting on the floor, shoulders low, elbow flexed at 90° and forearm in the neutral position (28). After the verbal command, the voluntary performed the maximum isometric contraction of the dominant limb, obtaining at least three measures at one-minute intervals, considering the mean value for analysis.

Assessment of physical activity level

International Physical Activity Questionnaire (IPAQ)

The level of physical activity was assessed using the International Physical Activity Questionnaire — short version (IPAQ). This tool was developed to estimate the habitual level of physical activity of populations from different countries and sociocultural contexts (29, 30).

Then, at the end of the application of the questionnaire, the level of physical activity was classified according to the categories of the IPAQ (31).

The categories take into account criteria of frequency, duration and type of physical activity. Thus, the individuals were classified as sedentary, insufficiently active (A or B), active and very active. The criteria and, consequently, the amount of physical activity performed increase from sedentary to very active, that is, a sedentary person is classified as such because not even 10 continuous minutes of physical activity are performed per week, while a very active person performs a certain amount of vigorous activities at a certain frequency and duration or a combination of strong, moderate activities and walking, also with certain frequencies and lengths (31).

*Data analysis*

The data were analyzed descriptively using means, standard deviations, absolute figures and percentages. The Kolmogorov-Smirnov test was applied to check the normality of the data. To compare the variables (systolic and diastolic) BP, HR, SpO2 and BORG scale for UL dyspnea and fatigue before and after the PBRT, Wilcoxon's non-parametric test was applied.

To study the correlations between the variables, Spearman's correlation coefficients were used, respecting the distribution of the data. Significance was set at $p < 0.05$. The statistical software used was Statistical Package for the Social Sciences (SPSS) for Windows, version 17.0.

## Results

In total, 50 individuals were classified, including 17 men (34%) and 33 women (66%). As regards the classification of the level of physical activity, 54% of the individuals were classified as active (n = 27), 16% very active (n = 8), 16% insufficiently active B (n = 8), 10% insufficiently active A (n = 5) and 4% sedentary (n = 2). The distribution of the mean coefficients for the anthropometric variables, GS and number of rings moved during the 6PBRT according to gender is displayed in Table 1.

**Table 1** - Distribution of mean coefficients for anthropometric variables, GS and number of rings moved in 6PBRT according to gender

| Variables | Men (n = 17) | Women (n = 33) |
|---|---|---|
| Age (years) | 23.41 ± 3.58 | 23.27 ± 3 |
| Body mass (Kg) | 76.13 ± 13.37 | 59.88 ± 8.13 |
| Height (cm) | 164.65 ± 38.48 | 163.67 ± 6.10 |
| BMI (Kg/m$^2$) | 25.09 ± 3.91 | 22.26 ± 2.36 |
| GS (Kgf) | 41.28 ± 7.13 | 25.26 ± 4.68 |
| Number of rings moved in 6PBRT | 277.29 ± 27.40 | 277.76 ± 38.01 |

Note: Kg: kilogram; cm: centimeter; BMI: body mass index; Kg/m$^2$: kilogram per square meter; GS: Grip strength; Kgf: kilogram-strength; 6PBRT: 6-minute Pegboard and Ring Test.

The changes in the physiological variables and the BORG scale for UL dyspnea and fatigue before and after the 6PBRT are distributed as shown in Table 2. A statistically significant difference was found for the variables systolic and diastolic BP, HR, SpO2 and BORG scale for UL dyspnea and fatigue before and after the 6PBRT (Table 2).

**Table 2** - Distribution of means and comparison of blood pressure, heart rate, peripheral oxygen saturation, Borg scale for UL dyspnea and fatigue before and after 6PBRT variables

| Variables | Before test | After test | p |
|---|---|---|---|
| Systolic blood pressure (mmHg) | 106.16 ± 9.97 | 117.18 ± 12.2 | < 0.001* |
| Diastolic blood pressure (mmHg) | 68.46 ± 7.53 | 73.28 ± 9.01 | < 0.001* |
| Heart rate (bpm) | 76.94 ± 12.81 | 98.14 ± 14.18 | < 0.001* |
| SpO2 (%) | 97.48 ± 1.09 | 97.8 ± 0.85 | 0.009* |
| Borg scale – Dyspnea | 0.02 ± 0.09 | 0.47 ± 0.82 | < 0.001* |
| Borg scale – UL Fatigue | 0.14 ± 0.36 | 3.06 ± 2.01 | < 0.001* |

Note: mmHg: millimeters of mercury; bpm: beats per minute; SpO2: peripheral oxygen saturation; %: percentage; *: Wilcoxon test and $p < 0.05$.

When the correlations between the number of rings moved, level of physical activity, GD and BMI were studied, no significant correlation was found between the variables ($p > 0.05$), as demonstrated in Table 3.

**Table 3** - Spearman correlation coefficient between variables number of rings moved in PBRT, level of physical activity and BMI

| | Number of rings moved in 6PBRT | |
|---|---|---|
| | Correlation coefficient (r) | p |
| **Level of physical activity** | 0.076 | 0.602 |
| **GS** | - 0.008 | 0.956 |
| **BMI** | 0.031 | 0.829 |

Note: 6PBRT: 6-minute Pegboard and Ring Test; GS: Grip strength; BMI: Body mass index.

## Discussion

Assessing the UL is an essential tool to identify possible functional capacity limitations concerning physical efforts in the upper limbs. And among the assessment methods, the 6PBRT stands out because of its low cost and easy application, which facilitates its access and use in clinical practice.

In this study, while assessing the UL functional capacity by means of the 6PBRT, the physiological variables BP, HR and SpO2 presented small but significant alterations between the pre and the post-test, as demonstrated in the study results. These findings are expected, as they are acute physiological reactions of the organism in response to physical exercise (32).

Concerning the feeling of dyspnea, it was practically absent after the 6PBRT. On the other hand, UL fatigue varied in healthy individuals. In individuals with chronic pulmonary disease, on the other hand, limitations in exercises involving UL (due to dyspnea and/or fatigue) are frequent, as Velloso et al. (33) demonstrated in their study, in which they assessed 35 individuals with COPD before and after eight weeks of pulmonary rehabilitation, with three sessions per week. Each session consisted of 30 minutes of treadmill walking at 80% of the maximum HR, 30 minutes of UL exercises with diagonal movements and 30 minutes of stretching and relaxation. After the training period, the maximum sustained load at the end of the incremental UL test increased and the feeling of dyspnea and UL fatigue decreased during ADLs, indicating that, in patients with chronic pulmonary diseases that limit the ADLs, UL training can reduce the feeling of dyspnea and UL fatigue.

In addition, there was no correlation between the number of rings moved in the 6PBRT and the level of physical activity. This result can be partially explained by the great variation in the activities the volunteers performed. In many of them, the lower limbs were the focus, like in walking and running for example. In addition, the study sample was not homogeneous in terms of gender, with practically twice as much women as men, which may have contributed to this lack of correlation.

Besides the lack of correlation between the level of physical activity and the number of rings moved in the 6PBRT, there was no correlation either between the GS and the number of rings moved. This result may have been due to the fact that the muscle strength does not influence the test performance, which requires more muscular resistance to maintain the UL high to move the rings than actual muscle strength. Ike et al. (23) developed a study in 2010 in which they submitted 12 individuals diagnosed with moderate to very severe COPD to UL strength training. These were divided in two groups (control group and trained group). The trained group trained UL strength three times per week for six weeks with a load of 80% of a maximum repetition (1MR). Before and after the training, the 1MR and 6PBRT tests were performed in both groups. The study results concluded that there was a significant increase in the muscle strength in the trained group, corresponding to 52% in the supine exercise ($p = 0.0008$) and 22% in the pulley exercise ($p = 0.03$). In the control group, there was no significant difference ($p > 0.05$) in muscle strength between the pre and post-treatment periods. As to the 6PBRT, there was no significant difference in both groups, despite the gain in muscle strength in the trained group, supporting the present study results, in which the muscle strength (measured through the GS) was not related with the number of rings moved in the 6PBRT.

Nevertheless, in a randomized study, Janaudis-Ferreira et al. (34) provided UL strength training to COPD patients, who were divided in two groups, being one control ($n = 18$) and one intervention group ($n = 13$). In the control group, only stretching sessions three times per week were performed during six consecutive weeks, totaling 18 sessions, with the same duration in the intervention group. The protocol applied in the intervention group consisted of UL resistance exercises with free weights, repeated between 10 and 12 times. The intervention group revealed higher performance in the 6PBRT ($p = 0.03$), concerning exercise capacity ($p = 0.01$), elbow flexion strength ($p = 0.01$), elbow extension strength ($p = 0.02$), shoulder flexion strength ($p = 0.03$) and shoulder abduction strength ($p = 0.01$) in comparison to the control group. Thus, the gain in UL strength promoted performance improvements in the 6PBRT, demonstrating the influence of UL muscle strength on the test performance, differently from the present study results, in which no relation was found between muscle strength and the number of rings moved.

The BMI did not show correlation either with the number of rings moved in the 6PBRT, which can be explained by the fact that the BMI did not directly indicate the amount of body fat, and by the fact that the individuals remained seated during the test, which may not have caused interference of the BMI in the test performance.

In addition, the idea that high BMI levels imply low functionality is commonly associated, a fact that is not always true, as demonstrated in the study by Roncato et al. (35), in which the functional capacity of 45 women with a mean age of 65.3 years was assessed, in which the BMI was not correlated with the functional tests, supporting the present study results.

On the other hand, Gomes et al. (36) developed a study with 140 male and female adolescents between 10 and 14 years of age, divided in two groups, one with normal weight and the other overweight. The adolescents were submitted to a cardiopulmonary exercise test on an ergonometric treadmill. When comparing the cardiorespiratory variables in relation to the ventilatory anaerobic threshold between both groups, the group with overweight presented impaired cardiorespiratory capacity at the sub-maximum performance level on the cardiopulmonary exercise test when compared to the eutrophic group. Hence, the BMI can interfere or not in the performance of physical capacity assessment tests, varying according to the characteristics of the applied test and of the study population.

In view of the above, this study presents some limitations, such as the age range of the sample, as the 6PBRT was only performed with healthy adults, so that the results cannot be extrapolated to other populations. In addition, the study sample was not homogeneous for gender, suggesting further research with more robust and homogeneous samples to identify possible variations in different populations from distinct age ranges.

## Conclusion

The level of physical activity, GS and BMI did not influence the performance in the 6PBRT, as demonstrated by the absence of correlation between these variables. In addition, a slight increase in the (systolic and diastolic) BP, HR, SpO2 and in the feeling of dyspnea and UL fatigue was found after performing the 6PBRT.

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