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Functional reach and lateral reach tests adapted for aquatic physical therapy

Testes de alcance funcional e alcance lateral adaptados para fisioterapia aquática

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Abstract

Introduction: Functional reach (FR) and lateral reach (LR) tests are widely used in scientific research and clinical practice. Assessment tools are useful in assessing subjects with greater accuracy and are usually adapted according to the limitations of each condition. **Objective:** To adapt FR and LR tests for use in an aquatic environment and assess the performance of healthy young adults. Methods: We collected anthropometric data and information on whether the participant exercised regularly or not. The FR and LR tests were adapted for use in an aquatic environment and administered to 47 healthy subjects aged 20-30 years. Each test was repeated three times. **Results:** Forty-one females and six males were assessed. The mean FR test score for men was 24.06 cm, whereas the mean value for right lateral reach (RLR) was 10.94 cm and for left lateral reach (LLR) was 9.78 cm. For females, the mean FR score was 17.57 cm, while the mean values for RLR was 8.84cm and for LLR was 7.76 cm. Men performed better in the FR ($p < 0.001$) and RLR tests than women ($p = 0.037$). Individuals who exercised regularly showed no differences in performance level when compared with their counterparts. **Conclusion:** The FR and LR tests were adapted for use in an aquatic

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environment. Males performed better on the FR and RLR tests, when compared to females. There was no correlation between the FR and LR tests and weight, height, Body Mass Index (BMI), foot length or length of the dominant upper limb.

Keywords: Hydrotherapy. Assessment. Body Balance.

Resumo

Introdução: *Os testes de alcance funcional (AF) e Alcance Lateral (AL) são comumente utilizados em pesquisas científicas e na prática clínica. Os instrumentos de avaliação promovem maior segurança para avaliar cada indivíduo com maior acurasse nos resultados e são adaptados de acordo com as limitações de cada doença.* ***Objetivo:*** *Adaptar os testes de AF e AL para o ambiente aquático e verificar o desempenho de jovens saudáveis.* ***Métodos:*** *Foram coletados os dados antropométricos, e os jovens foram questionados se realizavam atividade física. Os testes de AF e AL foram adaptados para o ambiente aquático e aplicados em 47 sujeitos saudáveis com idade entre 20 e 30 anos. Repetiu-se três vezes cada teste.* ***Resultados:*** *41 mulheres e seis homens foram avaliados. A média do teste de AF para os homens foi de 24,06cm, alcance lateral direito (ALD) foi 10,94cm, alcance lateral esquerdo (ALE) foi 9,78cm para os homens. No grupo das mulheres, o AF foi de 17,57cm, para ALD 8,84cm e ALE 7,76cm. Homens apresentaram melhor desempenho no AF ($p < 0.001$) e no ALD do que as mulheres ($p = 0.037$). Os indivíduos que praticavam atividade física não apresentaram diferenças de desempenho nos testes.* ***Conclusão:*** *Os testes de AF e AL foram adaptados para o meio aquático. Homens apresentaram um melhor desempenho no teste de AF e ALD comparado com as mulheres. Os testes de AF e AL não apresentaram correlação com peso, altura, Índice de Massa Corpórea (IMC) e comprimento do pé e do MS dominante.*

Palavras-chave: *Hidroterapia. Avaliação. Equilíbrio Corporal.*

Introduction

Water's physical properties (1, 2) are, at the same time, destabilizing and facilitating factors to the maintenance of balance when an individual is immersed in water. Buoyancy and hydrostatic pressure, two physical principles of water, serve as basis for intervention strategies, whereas the water´s movement may also promote independence or reduce reaction time in balance performance (3). The water is a safe place for the rehabilitation of individuals with impaired body balance (4, 5). For this reason, there are ever more new treatment methods that need to be assessed with regard to the response of the body to this environment (4, 6 – 9).

An underwater force platform is the ideal tool to analyze ground reaction force. However, it is costly, which makes everyday use unfeasible for clinics and sport clubs. In addition to being expensive, the use of force platforms and the interpretation of the data obtained from them require specialized technical knowledge, which makes individualized prescription based on quantitative information about the forces acting on an individual's musculoskeletal structures difficult. Thus, in everyday practice, professionals find it difficult to handle this information and end up neglecting force control for the prescription of this technique (10).

Functional Reach (FR) and Lateral Reach (LR) tests are fast to administer and inexpensive, which makes their everyday use in clinics feasible. These tests aim at measuring the stability limits of the body's center of mass within a small support base (11 – 13). The FR test is defined as the maximum distance one can reach forward beyond arm's length while maintaining a fixed base of support in the standing position within the stability limits(11). The LR test challenges the stability limits of the body in the medial-lateral direction (12). FR and LR tests are validated, have high reliability levels and are widely used in scientific research and clinical practice (11, 12, 14 – 16).

The assessment tool proposed by Duncan (11) detects subtle changes in postural stability and identifies mechanisms of dysfunction. A number of improvement suggestions have been made to adapt it to the limitations of each condition, offer greater safety for subjects and obtain more accurate results (17 – 20) the abilities related to both FR tests are judged to differ because of the large difference in the testing method. This study aimed to compare center of gravity fluctuation, muscle activity and functional reach distance as measured by the original FR test and the elastic stick FR test. First, reach distance, back/forth and right/left moving distance of the center of gravity, and activity of the lower leg muscles (soleus and tibialis anterior. Nevertheless, there are still no proposals for the adaptation of the tool for use in the aquatic environment.

The FR and LR tests were selected because they can be acquired at relatively little cost and are easy to adapt for use in the water environments. Moreover, individuals who do not perform the test on the ground due to a high risk of falls or a lack of muscle strength, or those who are not able to stand with both feet on the ground or have limiting pain due to osteoarticular diseases may benefit from these tests, because the information obtained from them enables the prescription of more individualized and adequate interventions. Given the above, the aim of this study was to adapt FR and LR tests for use in an aquatic environment and assess the performance of healthy young adults on these tests.

Methods

This study was conducted at the hydrotherapy section of the physical therapy clinic of the Universidade Cidade de São Paulo – UNICID, after approval from the Research Ethics Committee of the Universidade Cidade de São Paulo – UNICID (Protocol number: 13256078 / 2006).

Forty-seven healthy physical therapy undergraduate students aged 20-30 years were recruited. Inclusion criteria were healthy young adults who did or did not exercise regularly. Exclusion criteria were: neurological diseases, musculoskeletal disorders, recent fractures, presence of pain, history of falls in the previous year, complaint of dizziness, systemic arterial hypertension, diabetes mellitus, use of assistive gait devices, alterations in range of motion of shoulders and elbows, and individuals not adapted to the aquatic environment.

All participants gave written informed consent. First, all patients had a complete anamnesis. They were asked whether they exercised, how often, what kind of physical activity they performed, and which was their dominant upper limb (UL). Next, we assessed anthropometric data, such as weight, height, length of the dominant UL (measured from the acromion to the third fingertip) and foot length (measured from the heel to the hallux or to the second fingertip, whichever was longer).

To check whether the subjects were clinically stable, in the initial clinical assessment we measured their blood pressure, heart rate and respiratory rate at rest and outside the swimming pool.

In order to adapt the FR and LR tests for use in an aquatic environment, we used three polyvinyl chloride (PVC) pipes, two lateral pipes and one upper pipe connected by a bend of the same material. A tape measure was affixed to the upper pipe, which was at the level of the subject's acromion process. The two lateral pipes were attached with a rope to the support bar on one side of the swimming pool (Figures 1 and 2). All tests were performed at the physical therapy clinic of the Universidade da Cidade de São Paulo (UNICID) in an indoor swimming pool heated to 34º C, measuring 3 meters long, 3 meters wide and 1.20 meters deep.

During the FR test, the subject was instructed to stand perpendicular to the pool wall, with their feet together, right shoulder aligned to the tip of the tape measure and flexed to 90º, elbow extended, wrist neutral and fingers flexed, without touching the tape. The tape measure was positioned at the level of the subject's acromion process.

In the LR test, the subject was immersed to the level of the iliac crests. In some cases, to adjust the subject's height to the desired height, a platform was placed under his/her feet. The examiner, who was in the swimming pool, recorded the initial measure of the test, which corresponded to the position of the third metacarpal on the tape measure. Next, subjects were requested to lean forward as far as possible, their feet not leaving the ground, and the final measure obtained was recorded. The test was repeated thrice for each individual.

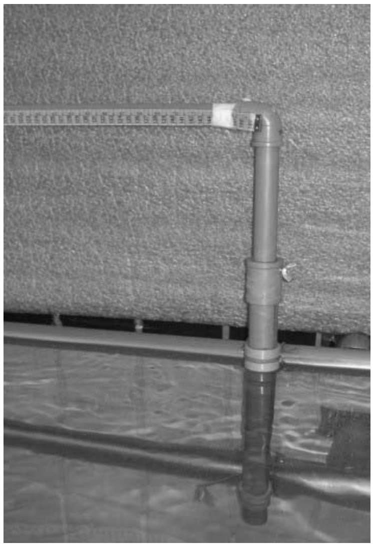

Figure 1 - Measurement equipment.

Figure 2 - Tape measure position.

The LR test was performed with both UL (left and right), with the subject's feet together, without touching the tape measure, the assessed UL abducted to 90º, elbow extended, wrist neutral and fingers extended and the other upper limb along the body. The tape measure was placed at the level of the subject's acromion process. The examiner, from inside the pool, recorded the initial measure, which corresponded to the position of the third fingertip on the tape measure. Next, the subject was asked to move as far as possible towards the side of the limb with shoulder abduction, without flexing the knees, rotating the body or flexing the trunk. Then the final measure was recorded. Both upper limbs were measured thrice.

The validation study of the FR and LR tests indicates that, during the first test, the feet shoud be positioned on a comfortable support surface (11) and during the latter test, there should be a 10-centimeter distance between the medial heels at a 30º angle outward from each foot (12). Notwithstanding, in this study we used the position with feet together in both tests, in order to standardize subjects' foot position, as water refraction could have interfered with the visualization of the real position of the feet underwater.

Statistical analysis

The data were statistically analyzed by using software (SPSS, version 18, SPSS Inc, Chicago, Ill). We performed descriptive analysis of categorical numerical variables, and frequency distribution of categorical nominal variables. Next, the data were checked for normality, using a Kolmogorov-Smirnov *test.*

Pearson's correlation coefficient was used to assess the correlation between parametric variables. The correlation values were ranked as follows: $0 < r < 0.3$ (weak correlation); $0.3 < r < 0.6$ (moderate correlation); $0.6 < r < 1.0$ (strong correlation) (21).

The *Mann-Whitney U* test and Student's t-test were used to compare the results of the reach tests, according to the following factors: performance of physical activity, gender and dominant UL.

Results

We assessed 47 healthy young adults (41 females and 6 males), aged 20-26 years (21.83 ± 1.2 years). Most participants (n = 44, 6 males and 38 females) were right-handed.

The anthropometric characteristics are depicted in Table 1. Table 2 shows the FR, RLR and LLR values for all subjects and Table 3 depicts reach values according to the performance or not of physical activity.

No statistically significant difference was found when correlating weight, height, BMI, foot length and dominant UL, and the FR and LR tests. Men performed better than women in the FR ($p < 0.001$) and RLR tests ($p = 0.037$).

Performance of physical activity did not interfere with reach performance in women (FR: $p = 0.61$; RLR: $p = 0.93$ and LLR: $p = 0.96$) or in men (FR: $p = 0.12$; LLR: $p = 0.36$), except for the RLR ($p < 0.01$).

Because all male participants were right-handed, it was not possible to verify whether the dominant UL influences the performance of tasks in males. The dominant UL does not seem to interfere with reach performance in women (FR: $p = 0.39$; RLR: $p = 0.42$; LLR: $p = 0.27$).

Table 1 - Anthropometric characteristics

	Weight(kg) (μ ± sd)	Height(m) (μ ± sd)	BMI(kg/m²) (μ ± sd)	Foot length(cm) (μ ± sd)	DUL(cm) (μ ± sd)
Female (n = 41)	59.21 ± 9.8	1.64 ± 0.1	21.89 ± 3.4	25.29 ± 7.4	72.61 ± 8.7
Male (n = 6)	75.05 ± 7.2	1.78 ± 0.0	23.71 ± 1.8	26.75 ± 0.5	80.33 ± 5.0

Note: BMI, Body Mass Index; DUL, dominant upper limb.

Table 2 - Values of Functional Reach and Lateral Reach

	Male (n = 6)				Female (n = 41)			
	Min.	Max.	Mean	sd	Min.	Max.	Mean	sd
FR	17	30	24.06	4.2	10	26	17.57	4.1
RLR	8	14	10.94	2.4	3.33	25.67	8.84	5.4
LLR	6	13	9.78	2.9	4	14	7.76	2.4

Note: FR, Functional Reach; RLR, Right Lateral Reach; LLR, Left Lateral Reach.

Table 3 - Means e standard deviations of Functional Reach and Lateral Reaches according to practice physical activity

Groups	Gender	FR(cm) (μ ± sd)	RLR(cm) (μ ± sd)	LLR(cm) (μ ± sd)
Pact (n = 14)	M (n = 3) F (n = 11)	26.78 ± 2.5 18.12 ± 3.4	13.00 ± 1.0 7.51 ± 2.0	11.00 ± 2.1 7.79 ± 2.5
SED (n = 33)	M (n = 3) F (n = 30)	21.33 ± 4.0 17.37 ± 4.4	8.89 ± 0.8 9.32 ± 6.2	8.56 ± 3.6 7.74 ± 2.4

Note: FR, Functional Reach; RLR, Right Lateral Reach; LLR, Left Lateral Reach; Pact, practice physical activity; SED, sedentary.

Discussion

The results obtained by our sample of healthy Brazilians on the FR and LR tests in a therapeutic pool were lower than those of tests administered on the ground (11– 13, 22). Silveira (13) administered the reach tests to a sample of the Brazilian population and found the following mean values for females aged 20-40 years: FR = 34.74 cm, RLR = 18.09 cm, LLR =18.79 cm. The values found for males were as follows: FR= 37.49 cm, RLR= 20.19 cm, LLR= 21.32 cm.

Postural stability is the ability to maintain the projected center of mass within the limits of the base of support. The stability limits are not fixed but are modified according to the task, the body's biomechanics, and features of the environment (23).

The fact that the results obtained in this study were lower than those of studies with tests performed on the ground could be explained by the occurrence of anterior or lateral trunk displacement, because an immersed body comes under the effect of the metacentric effect. The metacentric effect is an immersed body's adaptation to align the center of buoyancy (which is under the water surface) and the center of gravity (which is out of the water). The distance between the intersection above the center of gravity and the center of buoyancy is a measure of the initial stability of the body (24, 25). Movement occurs and that movement is one of rotation to maintain symmetry and preserve body balance (26). This may justify the nonuse of maximum amplitude measurements in reach tests.

Another factor that may have interfered with the reach tests is that, as shown by Pöyhönen (27), an immersed body requires lower muscle activation and has reduced electromyography (EMG) amplitude due to antigravity forces exerted on a body in water . A body immersed in water experiences reduced gravitational stress in muscles and joints, especially of the lower limbs. The response from these receptors may be decreased as a result of buoyancy forces (6, 27, 28. This effect may interfere with the neuromuscular and proprioceptive systems, preventing the subject from having a similar performance to that achieved on the ground. Nevertheless, the effects of reduced gravity on the neuromuscular system, especially on the muscle spindles and the proprioceptive system, during maximum and submaximum voluntary contraction are relatively unknown.

Another factor that may have influenced the results of the tests is the speed of trunk displacement, because, during movement in water, drag forces act opposite to the relative motion of the body segments (29) and, the faster the movement, the greater the drag forces acting upon the body. In this study, trunk displacement speed was standardized for the FR and LR tests. There was no correlation between the FR and LR tests and weight, height, BMI, foot length or length of the dominant UL. When walking immersed in water up to the xiphoid process, buoyancy forces reduce body weight by 71% (29), which may explain the noncorrelation between the reach tests and weight and BMI. Hydrostatic pressure and buoyancy support the body in remaining in the upright position. This may explain the noncorrelation between the tests and foot length. Silveira (13) investigated a sample of the Brazilian population and reported that other factors may also influence functional reach, namely: fear of falls, joint flexibility of ankle and hip, as well as lower limb muscle strength, especially of plantar flexors, dorsiflexors and hip abductors and adductors. Body composition, immersion level, adaptation to the water environment and water temperature are factors that may have influenced our test results.

Although we found no statistical difference in LLR between genders, the men still achieved higher values than the women, which corroborates the Brazilian literature (13). One factor that may have interfered with the test is density of the human body, which is slightly lower than water density (0.974). Additionally, males have, in average, a higher body density than females (30). Since females show greater reductions in weight-bearing in water than males, they tend to float more easily. This fact and the action of the metacentric effect led to a greater difficulty in maintaining body stability during the performance of the anterior and lateral reach tests. This is in line with the findings by Haupenthal (10) and Barela (31), who state that body mass also shows association with the antero-posterior force of an immersed body.

Although a difference was only found for males and not for females, performance of physical activity seems to interfere with FR and LR. Large group variability may have interfered with the RLR results obtained in this study. Therefore, results from other studies with larger and more homogeneous samples are needed to confirm this finding. Further studies with bigger and matched samples are needed to confirm whether the dominant side can or cannot interfere with the performance of tasks in an aquatic environment.

The limitations of this study include the small number of male undergraduate physical therapy students at UNICID. Thus, new studies are required to corroborate our findings that males perform better than females on the FR and RLR tests. Moreover, psychometric studies of the instrument may also be needed for it to be used effectively in clinical practice and scientific research.

Despite the study limitations, the influence exerted by the physical principles of water, and the fact that the results obtained in this study were lower than those of studies with tests performed on the ground, we found that the reach tests adapted for use in water environments can be considered an additional assessment tool in aquatic physical therapy.

Conclusion

The FR and LR tests were adapted for use in an aquatic environment. The results obtained on these tests were lower than those of tests performed on the ground, possibly because of the properties and effects of the water constituents, which may have interfered with the subjects' performance. Males performed better than females on the FR and LR tests, because they have higher body density, which reduces their buoyancy and gives them greater postural stability to perform the tests. There was no correlation between the FR and LR tests and weight, height, BMI, foot length or length of the dominant upper limb. Physical activity interferes with RLR in males. Further studies are needed to investigate the inter-examiner reliability of the tests and their applicability in aquatic physical therapy clinical settings, particularly in other populations.

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