ORIGINAL ARTICLE

# Inter-tester reliability assessment of the volumetric measurement of the hand in subjects without any changes in their upper extremities

## *Avaliação da confiabilidade interobservadores da volumetria das mãos em indivíduos sem alterações em membros superiores*

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## ABSTRACT

The purposes of the present study were to evaluate the inter-tester reliability of the volumeter and to determine the normative index in adults of both genders and without any changes in their upper limbs. The sample was composed of one hundred individuals (200 hands), 50 women and 50 men, with ages between 21 and 50, and with uncompromised upper limbs. The volume of each subject's hand was randomly measured through the volumetric method and the instrument used to evaluate them was a volumeter. This method was applied by 2 examiners and each patient was evaluated twice. Comparing the hands, gender, and examiners, we can observe that the mean of the right hands was always greater than that of the left hands, the mean volume of men's hands was always greater than the women's, and the mean of the second examiner was always greater than the first. From this analysis, considering values obtained with both examiners, we can notice that the final average was significant ($p<0.001$) to the difference between the right and the left hand in the general population, for women and for men. We can conclude that the results statistically significant to the final averages of volumetry were: for women, right hand with 402.40ml and left with 397.15ml; for men, right hand with 516.10ml and left with 505.30ml, and, in the general population, right hand with 459.25ml and left hand with 451.23ml. We can also conclude that the results are cohesive and reliable.

**Keywords:** Edema, Upper Extremity, Evaluation

## RESUMO

*Os objetivos do presente estudo foram avaliar a confiabilidade interobservador do instrumento volúmetro e determinar o índice normativo em indivíduos adultos do sexo feminino e sexo masculino sem alterações em membros superiores. A amostra foi composta por cem indivíduos (200 membros), sendo 50 do sexo feminino e 50 do sexo masculino, com idades entre 21 e 50 anos, sem comprometimento em membros superiores. O volume das mãos de cada indivíduo foi avaliado por meio da volumetria e o instrumento de avaliação utilizado foi o volúmetro. Este método foi aplicado por duas examinadoras, de modo que cada participante foi avaliado duas vezes consecutivas. Nas comparações realizadas entre os membros, sexos e examinadoras pode-se observar que a média do membro direito foi sempre maior que a do membro esquerdo, a média do volume das mãos dos homens sempre maior que a das mulheres e a média da segunda examinadora sempre maior que a da primeira. A partir de análise realizada, considerando os valores obtidos por ambas examinadoras, pode-se notar que a média final foi significante ($p<0,001$) à diferença entre o membro direito e o membro esquerdo na população geral, no sexo feminino e sexo masculino. É possível concluir que os resultados estão coesos e com boa confiabilidade e foram estatisticamente significantes para as médias finais da volumetria no sexo feminino, membro direito 402,40ml e membro esquerdo 397,15ml; sexo masculino, membro direito 516,10ml e membro esquerdo 505,30ml; e na população geral, membro direito 459,25ml e membro esquerdo 451,23ml.*

***Palavras-chave:*** *Edema, Extremidade Superior, Avaliação*

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## INTRODUCTION

The hand is an organ that is involved in practically all our daily life activities such as dressing, washing, eating and, by being frequently subject to accidents, it can compromise a variety of functions.[1,2]

After an injury, the formation of an edema is inevitable and it can limit movements and therefore lead to the formation of adhesions and excessive fibrosis.[2,3]

The edema is a sign frequently observed by therapists during the evaluation of hands indicating an inflammatory tissue reaction, a disturbance in the normal dynamics of the capillaries and the malfunctioning or compromising of the pumping mechanism of the veins and the lymphatic system. It is a defense reaction of the organism to the trauma and the result of physiological alterations that cause the increase in the volume of the region.[4,6]

When persistent, the edema slows the recovery process and generates morbidity, joint rigidity, pain, and other tissue distress, and can generate a state of functional incapacity by limiting muscular elasticity, decreasing the articular range, shortening the aponeurosis and, in certain cases, leading to tissue necrosis. This situation requires early detection, systematic monitoring, and control of its evolution so that the therapeutic procedures can be proposed or reviewed, thus avoiding undesirable future consequences.[3,5,7]

There is a series of procedures and evaluation instruments used on patients who present some type of compromising of the upper limbs.[4] Currently, the methods utilized are those recommended by the International Federations of the Hand Surgery and Therapy, and that present the best coefficients for validity, reliability, accuracy and well-defined standardization, taking into consideration the various factors that can alter the measurements. They present criteria for the gradation of the results, and the instruments are well calibrated to avoid systematic errors.[8]

To evaluate the edema is to quantify the volume of the hand, forearm, arm, and/or fingers in order to supply data about the evolution of the disease and to establish comparison data to monitor the response of the patient to the treatment modalities.[4]

In the therapy of the hand, the evaluation includes the application of measurement procedures of the edema with objective methods whose reliability is still being discussed. In the literature and in clinical therapeutics it is possible to identify some measurements such as the circumference, the eight-figure method, volumetry, bio-electronic impedance, and computer programs that make it possible to register the measurements.[1,4]

The use of water displacement as a way of measuring the volume of the hands has been an accepted practice since the beginning of the 50s.[9]

Displacement volumetry was introduced into medicine by Glisson, in 1622. It is one of the most useful standardized evaluating processes for measuring the edema to quantify the efficacy of the treatment. The measurement is made by the volumeter, a specially-designed recipient of translucent material (acrylic), in which we pour water at room temperature until the limit defined by a scupper, through which the excess water can drain.[4,7,10,11]

Usually, the comparison of results is made with the contralateral side, hence it is necessary to do the procedure with the compromised limb and with the non-compromised one. In that sense, the preoccupation of the researchers has been to try to establish normalcy levels and to interpret what would be abnormal. However, sometimes this is not possible, for the opposite side is not always preserved and there may be significant differences according to the dominance.[8]

One of the main advantages that volumetry offers is being a method that is simple and quick to apply, and is safe, precise, reproducible, non-invasive, and can be done by health professionals as a means to monitor the changes in the volume of a specific region of the body. Volumetric measuring may be contraindicated in the presence of wounds, external braces, percutaneous osseous synthesis, vascular instabilities, and plastered splints.[4,10,12]

## OBJECTIVE

The present study sought to evaluate the inter-tester reliability of the volumeter instrument and to determine the normative index in female and male individuals who had no impairments in their upper limbs.

## METHOD

This was a cross-sectional study, carried out at the Lar Escola São Francisco Rehabilitation Center (LESF) and at the Hospital São Paulo.

For a period of 76 days (from July 6 to September 20, 2006) one hundred individuals (200 limbs) were recruited with 50 females and 50 males, with ages between 21 and 50, with no impairments in their upper limbs.

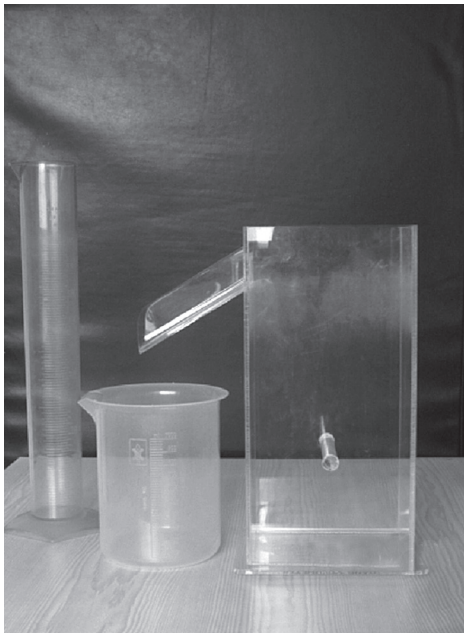

**Figure 1** - Volumeter of translucent material (acrylic) with the Becker collector and a 500ml graduated cylinder.

No individuals aged below 21 years or above 50 years or who presented any irregularities in their upper limbs participated in the study. People with cognitive deficits or any etiology were also excluded, for it would have jeopardized the correct understanding and performance of the measurement procedures.

Before the beginning of the experiment, the participants were informed about the research procedures and signed a Free and Clarified Consent Form, according to the Regulating Directives and Norms of Research involving Human Beings.

The volume of both hands of each individual was evaluated through volumetry, randomly in relation to their order of application. This method was applied by two examiners, so that each participant was evaluated two different times.

The hand volumeter used was (8cm x 13cm x 28cm), made of translucent material (acrylic), with product name "Hand Volumeter," made by Volumeter Unlimited, Phoenix, AZ 85032 *ndH*(figure 1), and it was filled with room temperature water, to the limit defined by an orifice, through which the water is poured.[4]

The hand and arm of the volunteer was left exposed and without any object that could alter the measurement, such as jewelry or clothing.[4]

The volunteer was positioned beside the instrument, remaining with the palm of hand in anatomical position during the procedure and the hand in the vertical position for as long as possible, to avoid contact with the sides of the

equipment. The hand was immersed slowly into the volumeter until it rested on a transverse bar, fitting the middle and ring fingers, with the thumb turned to the orifice. The position of the hand was maintained until the pouring of the water was completed in the collecting recipient. Later the person was instructed to remove the hand from the volumeter.[4,9]

The displaced water was carefully transferred to a 500 ml graduated cylinder.[4] Whenever more than 500ml of water was displaced, the cylinder was filled more than once and its volumes added. Thus, the hand volume was measured by the total volume of water decanted.

The time necessary for the evaluation of each participant was approximately ten minutes; the time stipulated by the Brazilian Society of Hand and Upper Limb Therapists.[4]

After the evaluation was finished, the results obtained were analyzed statistically. For this work the following parametric tests were used: Paired T-Student, ANOVA, Pearson Correlation, Intraclasses Correlation Index (ICI), and Correlation Test. In completing the descriptive analysis, the Confidence Interval technique was utilized for the mean. A significance level of $p< 0.05$ was established for this work.

## Characterization of the Sample

The sample was composed of one hundred people, with one half (50%) female and the other half (50%) male. The age of the participants ranged from 21 to 50 years old, with an average age of 29.43 years. Of the participants, 92% were right-handed and 8% were left-handed. In relation to their professions, 72% were distributed in the area of services and in the technical area (general helper, administrative assistant, secretary, janitor, house-wife, security, orthopedic technician, nursing technician, and others), and 28% was composed of professionals with a college degree.

# RESULTS

For the females, the volume average of the right hand obtained by the first examiner was 400.90ml and by the second examiner was 403.90ml. For the volume of the left hand, the average found by the first examiner was 396.40ml and by the second examiner was 397.90ml. The Intraclasses Correlation Index (ICI) found for the right hand was 99.6% and for the left hand was 99.3%.

The results of the volumetry done with females have shown that the p-value of the right hand considered statistically significant due to the level of significance was 0.005, while for the left hand, the p-value was not significant (0.261).

For the males, the average volume of the right hand obtained by the first examiner was 514.50ml and by the second examiner was 517.70ml. For the volume of the left hand, the average found by the first examiner was 502.40ml and by the second examiner was 508.20ml. The Intraclasses Correlation Index (ICI) found for the right hand was 99.3% and for the left hand was 97.4%.

The results obtained through the volumetry done with males have shown that the p-value for both hands was considered significant due to a level of significance of 0.033.

For the general population, considering both genders, the volume average for the right hand obtained by the first examiner was 457.70ml and by the second examiner was 460.80ml. For the left hand volume, the average found by the first examiner was 449.40ml and by the second examiner was 453.05ml. The Intraclasses Correlation Index (ICI) found for the right hand was 99.7% and for the left hand was 99.1%.

In the general population, the results of the volumetry have shown that the p-value of the right hand was considered statistically significant (<0.001) and for the left hand, the p-value considered statistically significant due to a significance level of 0.016.

The results of the comparison made between the male and female genders, with each examiner, have shown that males present a larger average than the females.

The results of the comparison made between the genders have shown that the right hand always presents larger averages. For females, the right hand was on average 5.25ml larger than the left hand, and for males, the average presented a difference of 10.8ml for the right hand.

**Table 1** - Comparison of the volumetry (milliliters – ml) considering the results obtained by both examiners.

| Both Examiners | GENERAL | | FEMALES | | MALES | |
|---|---|---|---|---|---|---|
| | Right Hand | Left Hand | Right Hand | Left Hand | Right Hand | Left Hand |
| Mean | 459.25 | 451.23 | 402.40 | 397.15 | 516.10 | 505.30 |
| Median | 455.00 | 455.00 | 405.00 | 395.00 | 515.00 | 505.00 |
| Standard Deviation | 81.33 | 79.23 | 53.97 | 56.97 | 62.09 | 58.87 |
| Coefficient of Variation | 17.7% | 17.6% | 13.4% | 14.3% | 12.0% | 11.7% |
| Confidence Interval | 11.27 | 10.98 | 10.58 | 11.17 | 12.17 | 11.54 |
| ICI | 99.1% | | 99.1% | | 97.0% | |
| p-valor | <0.001* | | <0.001* | | <0.001* | |

* p-value < 0.05

The comparison of the volumetry between the right hand and the left hand of males and females and in general, considering the results obtained by both examiners is contained in Table 1.

We can say that the final average was significant ($p<0.001$) to the difference in the general population between the right hand and the left hand, of 459.25ml and 451.23ml, respectively. The final average was significant ($p<0.001$) to the difference in females between the right hand and the left hand, of 402.40ml and 397.15ml, respectively. The final average was significant ($p<0.001$) to the difference in males between the right hand and the left hand, of 516.10ml and 505.30ml, respectively.

The Intraclasses Correlation Index (ICI) found for the general population was 99.1%, for females was 99.1%, and for males was 97.0%. These values indicate that the volumetry done by the two examiners is reliable.

# DISCUSSION

In the present study, the age of the one hundred participants without irregularities in their upper limbs varied from 21 to 50 years old, with an average age of 29.43 years, similar to the results found by Maihafer et al. in which in a sample of 50 normal volunteers, the average age was 29 years and in the study by Farrell et al. that evaluated 15 individuals without edemas in their hands, presenting an average age of 29.7 years.[13,14]

In relation to the profession of the participants, 72% were distributed in the services and

technical areas, and the remaining 28% was composed of professionals with college degrees. Studies about the professions of participants evaluated were not found in the literature.

In this study 92% of all the participants were right-handed and the remaining 8% were left-handed, similar to the results found by Engler & Sweat who evaluated 108 females, with 92.6% of them being right-handed and 7.4% being left-handed.[15]

Among the methods utilized in the clinical practice, the measurements taken by displacement of water seemed to be more precise, for the results presented one single value. It is noted that the results of this study for the methods of measurement by volumetry are cohesive and show good reliability (ICI around 0.98). These can be extrapolated to a population analysis, for they were quite homogeneous. That is, they presented little variation from among a very large sampling.[10,13]

Considered by many as 100% reliable by the exact evaluation of the volume of the hand and for estimating its variations as a function of determined factors, volumetry is still today seen by authors such as Perrin and Guex as the "gold standard," for it includes the entire limb.[16,17]

Volumetry supplies a precise, reliable, and reproducible measurement when the equipment instructions are followed. Various authors have made studies showing the precision of the volumeter as fine as 1% of increase in the volume of the hand.[9,15,18,19]

Eccles[9] was the first to make a study that determined the precision of a specially-designed volumeter (the level of precision is the division of measurement error by the real value, free from error). The precision of this unique volumeter was determined as being approximately 1%, using only one designed object.

DeVore & Hamilton, as well as Smith et al, also utilized specially-designed volumeters to confirm the precision of the measurement.[18,19]

Boland & Adams reported high reliability in volumetric measuring utilizing a specially designed volumeter (ICI=0.99).[20]

In 1991, Waylett-Rendall & Seibly studied the precision of a commercially available volumeter and discovered that it was accurate to 1%, in the same way as the one manufactured.[21]

Many studies have reported reliability in volumetric measurements, however, that was their claim based on the use of analyses that did not include the calculation of measurements for standard reliability (ICI or SEM).[22-24]

Boland & Adams reported high intra-tester reliability (ICI=0.99) for two successive measurements utilizing a specially designed volumeter. None of the researchers already mentioned, however, has established the intra-tester reliability in the measuring of hand volume.[20]

Guidince & Faghri reported separately on intra-tester reliability in normal hands of ICI=1.0, but both studies utilized small samples, 5 and 10 hands, respectively.[24,25]

Pellechia reported in his study that the ICI intra-tester reliability of the volumetric measurements was 0.99 (SEM=7.4ml).[26]

Farrell et al reported that the resulting ICI values for the inter-tester reliability in the clinical and university scenarios, were high for the total group of participants (0.99) utilizing the first value as much as the average value.[14]

Vasiliauskas et al reported a difference between the first and the second measurement in the left and right hands of 8.7ml (standard deviation 7.9) and 8.4ml (standard deviation 7.7), respectively. They also reported their studies as having a correlation of r=0.99, indicating a high reliability in the re-test.[23]

In this study, no re-testing was done, which is a third evaluation after an interval of time. However, we suggest that this aspect be approached in later studies, for lower variability and higher volumetry reliability.

In the present study, from the results comparing the volume measurements between the two examiners, we can observe that the average of the second examiner is always higher that the average of the first examiner. This variation probably occurred due to the instability of the liquid medium, since most participants evaluated were not able to keep their upper limbs completely still during the measuring.[5]

Maihafer et al observed that the consistency of positioning of the part of the body was a critical point in his study, and the patient's hand needs to remain still for the measurement to be valid.[13]

In the current study, the results of comparison between the females and males with each examiner showed that there is a statistically significant average difference between the genders. It is also observable that males present a higher average in relation to the females, similar to the results found by Farrell et al in a study carried out in clinical and university scenarios.[14]

Many studies utilize volumeters basically for female populations, particularly in disorders such as lymphedema. Karges et al,[27] Megans et al,[28] and Sander et al,[29] independently made studies on females with a diagnosis of primary or secondary lymphedema and apparent edema in any part of the upper extremity.

An edema of the upper limbs can cause a diminution in the movement of the articulations and limitation in the general function, as well as hinder manual dexterity.[13,18]

In this study, the results of the comparison made between the right and the left limbs of individuals, without considering the dominance, have shown good reliability, with ICI of 0.99 for females, and ICI of 0.97 for males. In the Farrell et al study, the values found were ICI of 0.99, 0.95, 0.98 for males and the evaluations with females reported ICI of 0.89, 0.83, 0.88.[14]

In the present study, the comparison made between the limbs also showed that the right limb has higher averages, similar to the results found by Engler and Sweat who evaluated 100 right-handed females, with the right arm an average of 41ml larger than the left.[15]

The asymmetry present in human beings in relation to the use of hands in activities, that is, the frequent preference for one of the hands in one-handed tasks, is a factor that has varied implications which is why it must be taken into consideration in hand evaluations.[30]

We suggest that future studies on variability and reliability of volumetry be made using samples that include patients who have traumas, edemas, deformities, or who present anomalies, for the generalization of results for greater populations.[13,14,30]

## CONCLUSION

From this study we can conclude that the results were statistically significant for ascertaining: a final average volumetry for females at 402.40ml for the right limb and 397.15ml for the left limb; a final average for males at 516.10ml for the right limb and 505.30ml for the left limb; and a final average for the general population at 459.25ml for the right limb and 451.23ml for the left limb.

It is concluded also that the results in this study are cohesive and have good reliability.

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