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PERFORMANCE OF WEIGHING SCALES INSTALLED IN SELECTED HOSPITALS AND HEALTHCARE CENTRES IN DAR ES SALAAM

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ABSTRACT

Calibration and verification of weighing scales installed in hospitals and healthcare centres is indispensable to ensure its performance accuracy. A study was conducted to ascertain the performance of weighing scales in Ilala, Kinondoni, and Temeke hospitals located in Dar es Salaam region. The study administered fifty questionnaires to gather data from individuals working in these hospitals and healthcare centres as well as performing actual test of the installed scales. During the actual test, it was found that 38% of the scales delivered correct results, 48% were partially correct and 14% were incorrect. It was also found that 18% of tested scales were verified and stamped while 82% were neither stamped nor verified. Furthermore, the findings from the respondents show that 80% of the scales have not been repaired since they were purchased, 2% were repaired only once a year, while 18% were repaired at least once a year. It is concluded that the overall performance of the hospitals' weighing scales was not satisfactory. This is because only 38% of the scales delivered correct results while 62% delivered uncertain results. It is recommended that hospitals and healthcare centres should purchase weighing scales from the approved supplier by the Weight and Measures Agency (WMA) as this will minimize the poor performance of the scales used. It is also recommended that the Weight and Measures Agency (WMA) should establish a regulation that subjects the scales to metrological inspection and control, as well as raising awareness of the users of the scales on their proper use and storage.

Keywords: *Calibration, Verification, Medical Weighing scales and Performance*

INTRODUCTION

Background Information

The consciousness and importance of calibration and verification of weighing scales in industry and trade, has reached a great point. This is due to the fact that calibration and verification of scales used for trade are mandatory (Weight and Measures Act, 340). Moreover, according to Tanzania Weights and Measures Act (1983) and its regulations, weighing scales are required to be verified once every year (URT, 1983). Therefore, calibration and verification should be carried out on those scales used for trade and all measuring and weighing instruments used as per technical requirements. This process is therefore practiced to ensure correctness, repeatability, consistency and accuracy of the weighing instruments such as scales (National Bureau of Standard, 1983).

It is argued that weighing scales installed in hospitals are very important and therefore, it is undebatable that these scales require calibration and verification every now and then. Accurate weighing in hospital environments ensures hospital personnel to issue an appropriate dosage of medicines and other treatment requirements. Hence, since the scales are used regularly, it is recommended that they should be verified and calibrated accordingly.

According to Miriam et.al (2020), Tanzania hospitals weighing scales are not calibrated regularly as they are not subject to metrological control. Evans and Best (2014) also stressed that calibration of weighing scale ensures accurate and consistent patient weight readings which are critical to consistent and effective patient outcomes. Conversely, miscalibrated or inaccurate scales can cause inconsistencies that can lead to improper treatment.

It is also argued further that incorrect weighing scales in the hospital may cause death of patients (adults or children) due to wrong dosage caused by relying on an incorrect weighing instrument. Therefore, confidence in all weighing instruments used in hospitals is a major issue, without which, dosage of medicines in hospitals will always be subjected to multiple measurements and creating disputes due to differences in measurements. Moreover, the additional cost of such multiple measurements and in solving these disputes would considerably affect the efficiency of patient dosage and jeopardize the economy through increased medical costs.

Regardless of the metrological requirements, it has become a common practice in most hospitals to use weighing scales without even considering their metrological calibration and verification (Miriam et.al (2020), this is because weighing instruments used in hospitals are not subjected to metrological control by the WMA as required. This is due to the fact that hospitals are not obligated by the law to calibrate and verify their instruments which in the long run, may end up delivering wrong results to their patients and hence endangering human health during medication. Moreover, since most hospitals use multiple weighing scales, calibration is essential in order to ensure consistency and accuracy in their measurements (Stain et al., 2005).

Other past researches in this arena have been done in other countries such as Brazil (Luis et.al, 2006), where they compared different methods for weighing test in the calibration of non-automatic weighing instruments and found that among eight thousands (8,000) weighing scales in two hundred (200) hospitals, more than a third were inaccurate. Moreover, Stain et al. (2005) found that more than fifteen percent (15%) of the tested scales showed an average inaccuracy greater than 6 pounds. Therefore, due to this gap, the current study aimed to explore and test the performance of weighing instruments used in hospitals in Tanzania to unveil their status quo and their consistency in measurements.

Rationale of the Study

The study is expected to unveil the metrological status of weighing scales installed in hospitals and healthcare centres, especially on performance aspects. The study will also provide and disseminate information regarding the importance of calibration and verification of weighing instruments used in Tanzanian hospitals and healthcare centres. In addition, the expected findings will be a basis for advice on the procurement of weighing scales to the users. The research findings will also be valuable to the researchers as it will provide details regarding weighing scale error limits and accuracy that fit for a specific purpose. That is, frequent calibration and verification of weighing scales used in hospitals will in one area, enhance the community to mitigate malnutrition among children caused by incorrect weight delivered by the instruments. Furthermore, calibration and verification of hospitals weighing scales will benefit government not only by increasing revenues but also ensure health and safety of its people. Thus, by unveiling the needs to calibrate and verify hospital's weighing scales, policy makers will revisit the weights and measures regulations to include hospital weighing scales to the metrological assurance and control under WMA.

LITERATURE REVIEW

Theory Underpinning the Study

This study adapted the general theory of fundamental measurement developed by Scott and Suppes (1958). The theory explains the three fundamentals problems of measurement that should be taken into account as far as measurement is concerned. It briefly stated that the first problem to be addressed is the justification of assignment of numbers to object of phenomenon and the second is the justification of degree to which the assignment is unique and the last one is the error which is the amount observed value deviating from true value. In this study this theory was used to analyse various weighing scales installed in hospitals and healthcare centres regarding their accuracy when taking measurements. The study specifically focuses on the analysis of error when the measurement is taken, this will provide the information regarding calibration and verification of instruments (scales).

Weighing Instruments Legal Requirements

According to the method of operation, a weighing instrument such as scales is classified as an automatic or a non-automatic weighing instrument (OIML "R 76, 2004). International Organisation of Legal Metrology (OIML) recommendations number R 50, R 51, R 61 describe a non-automatic weighing instrument as the instrument that requires the intervention of an operator during weighing process to decide that the weighing result is acceptable (OIML, 1994).

In the technical perspective, all technical requirements apply to all types of weighing instruments, whether mechanical or electronic (OIML "R 76, 2006). However, they are supplemented or modified with additional requirements for instruments used for specific applications or designed for a special technology (Klaus & Ian, 2015) which normally intend to specify the performance, and not only on the design of an instrument so that technical progress is not impeded.

However, for special applications marked on the weighing instrument, an instrument may have weighing ranges in classes I, II, III and IIII as presented in figure 1.

Figure 1: Accuracy class for weighing instruments

Name	Symbol marked on instrument	Denomination used in this Recommendation
Special accuracy	(I)	I
High accuracy	(II)	II
Medium accuracy	(III)	III
Ordinary accuracy	(IIII)	IIII

Source: The International Recommendation of Legal Metrology (R 76-1), 2006)

Performance Testing for Weighing Instruments

According to OIML R 76-2 (1993), performance test is done by determining errors of measurement of a weighing instrument such as scales by verification requirements. According to the Weights and Measures Agency Act 340 (1993), before actual testing of any weighing scale, it should be visually inspected for its metrological characteristics that include compliance with several requirements.

During the test, the standard weights used to test weighing performance of an instrument (scale) may not deviate by more than 1/3 from the maximum permissible errors of this instrument. Performance testing of weighing instruments plays a substantial role in ascertaining the correctness of measurement results and procedures undertaken (Pendrill, 2011). This is due to the fact that when taking measurements of any quantity, internal checks are needed before performing the actual test, as systematic errors often can go unnoticed (Adriana & Alina, 2019).

Hence, as stipulated by OIML, R-76-1 (2006), the performance of weighing instruments (scales) should be determined based on their minimum capacity examples of which are presented in figure 2 in consideration of the accuracy class for weighing scales.

Figure 2: Accuracy class for weighing instruments

Accuracy class	Verification scale interval, e	Number of verification scale intervals, n = Max/e		Minimum capacity, Min (Lower limit)
		minimum	maximum	
Special (I)	0.001 g ≤ e*	50 000**	–	100 e
High (II)	0.001 g ≤ e ≤ 0.05 g 0.1 g ≤ e	100 5 000	100 000 100 000	20 e 50 e
Medium (III)	0.1 g ≤ e ≤ 2 g 5 g ≤ e	100 500	10 000 10 000	20 e 20 e
Ordinary (IIII)	5 g ≤ e	100	1 000	10 e

Source: The International Recommendation of Legal Metrology (OIML R 76-1), 2006)

Therefore, when conducting a performance test of weighing instruments that will eventually lead to its acceptance to suit the purpose, it is critically important to consider their maximum permissible errors. The OIML (2006) provides the maximum permissible error during initial verification and in service verification, as shown in figure 3.

Figure: Maximum permissible errors of weighing instruments

Maximum permissible errors on initial verification	For loads, m, expressed in verification scale intervals, e			
	Class I	Class II	Class III	Class IIII
± 0.5 e	$0 \leq m \leq 50\,000$	$0 \leq m \leq 5\,000$	$0 \leq m \leq 500$	$0 \leq m \leq 50$
± 1.0 e	$50\,000 < m \leq 200\,000$	$5\,000 < m \leq 20\,000$	$500 < m \leq 2\,000$	$50 < m \leq 200$
± 1.5 e	$200\,000 < m$	$20\,000 < m \leq 100\,000$	$2\,000 < m \leq 10\,000$	$200 < m \leq 1\,000$

Source: The International Recommendation of Legal Metrology (OIML R 76-1), 2006)

In addition, while carrying out performance test, the scale must be allowed to warm up and be loaded with a known mass not exceeding a maximum capacity at least three times (OIML R 76-2, 2007). Then, it is tested by loading the mass in two steps. The first step is loading in ascending order up to maximum capacity and the second step is unloading in descending order to zero (OIML R 76-2, 2007). In the process of loading and unloading of weights, it is important to handle with care because it may lead to change in its metrological characteristics (EN 45501:2015). The handling of the weighing body, such as the way it is loaded on balance, may influence the weighing results. Thus, operators are advised to follow the instructions provided before applying weights. Furthermore, smaller weights are to be handled with gloves to avoid direct contact with hand, leading to grease getting into weights and the subsequent warming up of the weights beyond the required temperature as specified by International Organization for Legal Metrology (OIML R76-1).

Measurement Errors in Weighing Scales Performance Testing

Maximum Permissible Error (MPE) of the scale must be known according to their class and standard mass used. Error should be calculated during loading and unloading by putting the smallest mass that can be detected and note the indications (I) on the scale for both forward and backward procedures (OIML R 76-2, 2007). Hence the scale's error is calculated as presented in equation 1:

$$E = I + \frac{1}{2}e - \Delta L - L \quad (1)$$

Where; e-scale verification interval; ΔL-small change in mass

Then, the corrected error is found by subtracting error at zero or smallest mass from the calculated error above as shown in equation 2:

$$E_C = E - E_0 \quad (2)$$

After conducting the testing, all the results should be recorded for both forward and backward procedures as indicated by arrows in figure 4.

Figure 4: Performance test results

Load, L	Indication, I ↓	↑	Add Load ΔL ↓	↑	Error, E ↓	↑	Corrected error, E_c ↓	↑	MPE

Source: The International Recommendation of Legal Metrology (OIML R 76-1), 2006)

In every test, if $|E_c| \leq |\text{MPE}|$, the instrument is **PASSED** otherwise, it is **REJECTED**

METHODOLOGY

The research employed descriptive research design such that the questions of what, how, where and when regarding the current status of a particular phenomenon or activities are to be answered through data collection. Furthermore, a quantitative data collection technique was adopted in data collection and quantitative data analysis was employed in analysing the data collected.

Population and Sampling

Samples from both hospitals, healthcare centres and weighing scale repairers in Dar es Salaam were used to analyse the performance of weighing instruments. The health care system in Tanzania as specified by www.pharmaccess.org, are categorized into five (5) levels. The levels are primary health care services (Level 1), district hospitals (level 2), regional referral hospitals (level 3), zonal referral hospitals (level 4) and national hospitals (level 5).

According to the ministry, as of 2016 there were a total of two hundred sixty three (263) hospitals from level 2 to level 5, and a total of six thousands eight hundred sixty eight (6868) primary healthcare such as dispensaries, clinics and health centres. The researcher considered level one (1) and level two (2) for sampling following the frequency of using weighing scales in daily routine which is high for the two levels, also in the two levels chosen, the level of treatment is moderate which simplifies the accessibility to the hospitals for data collection and finally the samples were considered following Covid 19 restriction in most of the medical/healthcare centres and hospitals.

Generally, forty (40) healthcare centres and ten (10) district hospitals were sampled for data collection following the population healthcare centres being higher than hospital's number. Among them, eleven (11) were from Temeke in which seven (7) belongs to level one (1) and four (4) to level (2), Ilala were 16 in which thirteen (13) belongs to level one (1) and three (3) to level (2) while twenty-three (23) were from Kinondoni in which twenty (20) belongs to level one while three to level 2.

On the other hand, twenty (20) weighing scale repairers were also sampled for data collection in three districts categorized by Weight and Measures Agency (WMA). The three district involves Kinondoni which contains a total of thirty-five (35) weighing scales repairer licenced in the year 2021, Ilala contains twenty-seven (27) weighing scales repairer and Temeke which contains sixteen (16) weighing scale repairer. Among the twenty (20) sample chosen, ten (10) weighing scale repairer were from Kinondoni district, six (6) from Ilala and four (4) from Temeke. The sample size for the weighing scale repairer were chosen considering their population in the respective district.

Data Collection Instruments

Data were collected using a questionnaire, key informants interviews and observations. The unstructured questions were provided to both hospital personnel and weighing scale repairers. Information on the metrological status (i.e. calibration frequency, repair frequency, verification and stamping etc.) of the weighing scale used by the medical people and repairers were collected through a number of questionnaires and interviews. The observation was also employed, especially in conducting performance tests of weighing instruments used in hospitals and weighing scale repair shops/centres.

Data Analysis
The collected information was then analysed using descriptive statistics software i.e. SPSS whereby frequencies and percentages were calculated to draw inference regarding weighing scale performance and their current metrological characteristics.

Limitations of the Study
The study was self-funded which limited the researcher to sample only Dar es Salaam region leaving many regions unreached due to lack of enough fund for data collection. Following the COVID 19 restrictions, researcher were sometimes denied to collect data in the hospitals or sometimes it required a long procedures to get a permit of data collection, this hindered the amount of information collected by researcher. Moreover, the respondents such as nurses and weighing scales repairer were hesitant to respond to some of the questions which the researchers believed to be caused by either time bound or lack of confidence in what they were responding.

RESULTS AND DISCUSSION
This section presents the results and discussion regarding the use of weighing scales, their verification and control, existence of weighing scale maintenance unit and performance testing.

Experience in Using Weighing Instruments
The respondents were asked about their experience in using weighing scales in hospitals or medical centres while undertaking their daily routine. The results as presented in table 5 show that the use of weighing scales in hospitals is indispensable whereby 94% of the respondents do use weighing scales while only 6% do not. The same findings has been pointed out by National Nurses Nutrition Group (2017), whereby the weighing scales are frequently used in determining body weights for adults and children in primary and secondary care centres.

Table 5: Use of weighing instruments by respondents

Use of weighing scales	Frequency	Percent (%)
Yes	47	94
No	3	6
Total	**50**	**100**

Nevertheless, the researcher wanted to know the verification and stamping status of weighing scales used in the hospitals. The results indicated in table 6 show that 82% of the respondent's weighing scales were not verified and stamped by the regulatory authority while 18% had their instruments verified and stamped.

Table 6: Verification and stamping status of weighing scales

Verification and stamping status	Frequency	Percent (%)
Yes	09	18
No	41	82
Total	**50**	**100**

4.2 Existence of Weighing Scales Maintenance Unit
The results as presented in table 7 show clearly that most of the hospitals visited (i.e. 68%) had no separate unit dealing with instruments control that includes purchasing, maintenance, advice on the use of the right instrument, etc. Moreover, 26% of the hospitals possess the instrument unit and only 3% have other units that sometimes act as instrument maintenance and control units.

Table 7: Instruments control unit

Availability of the weighing scale control unit	Frequency	Percent (%)
Yes	13	26
No	34	68
Any other	3	6
Total	**50**	**100**

The researcher also spotted weighing scale repair to find out how frequently the hospitals maintain and repair their weighing scales. The results as presented in table 8 indicate that 80% of the hospitals did not maintain their weighing scales, indicating that error in the measurement will be inevitable. Only one hospital (2%) did once in a year, while 18% repairs their instruments at least once in a year. The same results has been found by Evans et.al (2014) whereby of the tested weighing scales used in hospitals 72% had been not calibrated in the three consecutive years leading to errors during measurement.

Table 8: The frequency of weighing instruments repaired in a year

Weighing instruments repair	Frequency	Percent (%)
Once	1	2
Never	40	80
At least once	9	18
Total	**50**	**100**

On the other hand, the researcher also searched for information from the licensed weighing scale repairers. One of the pieces of information was how often they repair weighing scales from hospitals. The results as shown in table 9 show that most of them (60%) have never repaired hospital weighing scales, while 30% repaired only once in a year and 10% repaired at least once in a year.

Table 9: Weighing scale repaired by licensed weighing technician

Hospital weighing scale repair	Frequency	Percent (%)
Once	6	30
Never	12	60
At least once	2	10
Total	**20**	**100**

Metrological Status of weighing scales in the Surveyed Hospitals

The researcher also employed an observation technique whereby numeral hospitals and health centres were visited. The visitation was purposefully to know the metrological status of various weighing scales used in the hospitals and health centres, as indicated in table 10.

Table 10: Metrological status of hospital's weighing scale

S/No	Name	Model	Cap. (kg)	Type		Class	Status	
				Mech.	Dig.		Verf.	Rep.
1	Detecto Baby Scale	Not indicated	Nil	✓		Nil	X	X
2	Not indicated	Not indicated	250	✓		Nil	X	X
3	Seca (Germany)	Not indicated	210	✓		Nil	X	✓
4	FAZINI	Not indicated	200	✓		Nil	X	X
5	ADE	Not indicated	200	✓		Nil	X	X
6	CROWN (Baby Scale)	Not indicated	20	✓		III	X	X
7	Pedestal Baby Scale	Not indicated	20	✓		III	X	X
8	MOMERI(Germany)	Not indicated	120	✓		III	X	X
9	Salter Spring Balance	Not indicated	25	✓		III	X	X
10	Bathroom scale	Not indicated	120	✓		Nil	X	X

The findings show clearly that about 95% of the scales observed were not verified since they were bought. The results show that only one instrument has been repaired but not verified by a regulatory authority or any other accredited organization.

Performance Tests of Surveyed Weighing Scales in Study Hospitals

To ascertain the performance of weighing used in hospitals, the researcher lastly undertook the performance test of different weighing scales used in various hospitals visited during data collection. A total of hundred (100) weighing scales were tested for their performance, of which thirty-seven (37) were from Ilala, thirty-three (33) from Temeke and thirty (30) from Kinondoni.

A platform weighing scale was used as a reference standard during the test whereby the results from a tested scale are compared to that of the reference to ascertain their deviations. The test was conducted in two stages, such as loading standard weights (EURAMET, 2011) in ascending order and unloading standards weights in descending order.

The test results are presented in Table 11, and they are used to decide whether the scale is to be rejected (not fit for the purpose), repaired or accepted (fit for the purpose) as it complies with the prescribed standards.

Table 11: Performance test results for a sampled weighing scales

	LOADING				UNLOADING			
S/No	Standard Weights (kg)	Error prescribed division(s)	Error observed division(s)	Remarks	Standard Weights (kg)	Error prescribed division(s)	Error observed division (s)	Remarks
1	0	0	0	Balanced	150	±0.5	-0.5	Within
2	10	±0.5	+0.5	Within	140	±0.5	-0.5	Within
3	20	±0.5	+0.5	Within	120	±0.5	-0.5	Within
4	40	±0.5	+0.5	Within	100	±0.5	-0.5	Within
5	60	±0.5	0	Okay	80	±0.5	+1	Beyond
6	80	±0.5	0	Okay	60	±0.5	+1.5	Beyond
7	100	±0.5	-0.5	Within	40	±0.5	+2	Beyond
8	120	±0.5	-0.5	Within	20	±0.5	+1.5	Beyond
9	140	±0.5	-0.5	Within	10	±0.5	+1	Beyond
10	150	±0.5	-0.5	Within	0	±0.5	0	Balanced

Based on the results obtained, it is clear that 100% weighing scale provides accurate results during loading, while for unloading 60% of the readings deviated from the prescribed standards. Thus, the scale was recommended for repair, and afterwards, it should be used for the purpose thereof. The rest of the weighing scales were tested. The results as presented in table 11, was used to make a decision criteria of whether to reject (not fit for the purpose) if the deviation is beyond the limits and is predominant. Or the decision to reject for repair if the results lie in between the acceptable limits and beyond the limit or accept (fit for use) if the deviation is within limits or balance is predominant. With all the weighing instruments tested from Ilala, Temeke, and Kinondoni, 38% were accepted for use, 48% were recommended for repair, and 14% were completely rejected and not fit for use. A complete summary of the total number of scales tested and the decision is presented in table 12.

Table 12: Performance test results' summary

District	Scales tested	Fit for use	Rejected for repair	Not fit for use
Kinondoni	30	10	17	3
Ilala	37	15	15	7
Temeke	33	13	16	4
TOTAL	**100**	**38**	**48**	**14**

CONCLUSION AND RECOMMENDATIONS

Generally the results indicate that weighing scales are frequently used in hospitals in attending patients and clinical issues thus a reliable results should be produced by the scales. Most of the scales are not calibrated as per technical requirements following a greater percentage of unrepaired scales which delivers wrong results as shown in the research findings. Nevertheless, the scale control units were not considered of importance in most of the visited hospitals and healthcare centres which leads to their absence as seen in the results. Finally, the unrepaired and unverified scales contribute to poor performance of the weighing scales used in hospitals and healthcare centre as witnessed in the research findings.

Therefore, based on the study findings and in order to have accurate measurement results from hospital weighing scales, the following are recommended:

- Establishment of a weighing scales maintenance unit or lab for weighing scales control following ISO/IEC 17025 requirements. This is because the unit would provide guidance when it comes to control, purchase the right scales as well as their maintenance.

- The weighing scales used in the hospital should be purchased from a supplier approved by Weight and Measures Agency (WMA) with an approved list of weighing instruments.

- Weights and measures officers should raise more sensitization and awareness to the public on rules relating to weighing instruments.

- Weights and Measure Agency (WMA) prepare special characteristics (type, class and features) for weighing instruments to be used in hospitals. This will enhance the proper selection of weighing instruments during purchase instead of purchasing any weighing instrument for use in hospitals.
- Furthermore, the government should establish a regulation that will enforce weighing scales used in hospitals to fall under metrological control.

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REFERENCES

Adriana V. and Alina T (2019). Comparative Measurements on an Electronic Weighing Instrument. Mass laboratory: National Institute of Metrology (INM).

EN 45501:2015 - Metrological aspects of non-automatic weighing instruments.

EURAMET/cg-18/ v3/, (2011). "Guidelines on the Calibration of Non-Automatic Weighing Instruments".

Evans L., C. Best C (2014). “Accurate Assessment of Patient Weight.” *Nursing Times*. 110:12, p. 12-14.

ISO/IEC 17025 (2005), "General requirements for the competence of testing and calibration laboratories", Second edition.

Klaus F., and Ian C., (2015). Calibration of Weighing Instruments: Measurement Uncertainty, Minimum Weight and the Safe Weighing Range, *NCSLI Measure*, 10:3, 56-65.

METTLER TOLEDO (2001). Weighing Accuracy: Estimating Measurement Bias & Uncertainty
Of A Weighing.

Miriam, E., Nahya, S., Karama O., Donat S., Georgia R., Louise T., Hannah B., Joy E. (2020). Birthweight measurement processes and perceived value: a qualitative study in Temeke Hospital, Tanzania. BMC Pregnancy and Childbirth. Open access.

Mutai K.B. (2000). How to write a quality research proposal.

National Nurses Nutrition Group (2017) Good Practice Guideline: Obtaining an Accurate Body Weight Measurement in Adults and Children in Primary and Secondary Care Settings.
National Bureau of Standards, Handbook 44, (1983). "Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices," U.S. Department of Commerce, Washington, D.C.
OIML R76-1 - non-automatic weighing instruments Part 1: Metrological and technical requirements – Tests
OIML "R 76 (1992), Amendment 1 (1994). Non automatic weighing instruments; Part 1: Metrological and technical requirements –Test".
Pendrill, L.R (2011), "Which PTs have the greatest impact?" The Third International Proficiency Testing Conference, Iaşi, Romania, (27)28th − 30th September 2011.
Stein, Risa, PhD; C. Keith Haddock, PhD; Walker S.C. Poston, PhD, MPH; Dana Catanese; John. A. Spertus, MD (2005). "Precision in Weighting: A Comparison of Scales Found in Physician Offices, Fitness Centers, and Weight Loss Centers." *Public Health Reports*; p 266-270
The healthcare system in Tanzania (2016). www.pharmaccess.org
The International Recommendation of Legal Metrology (R 76-1, R 76_2,) 2006.