Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 09, Issue, 01, pp.25028-25032, January, 2019

ORIGINAL RESEARCH ARTICLE

OPEN ACCESS

ELECTRONIC BIOMEDICAL DYNAMOMETER FOR MEASUREMENT, ANALYSIS AND REGISTRATION OF PALMAR FORCE AND FORCE INFORMATION IN TIME

[2]Fernanda Guerreiro de Paula, *[1,2]Josivaldo G. Silva, [1]Andrés Batista Cheung and [1]Isabella Fenner Rondon

[1]Faculty of Engineering, Architecture and Geography, Federal University of Mato Grosso of Sul, State of Mato Grosso of Sul, BRA
[2]Post-Graduation Health Center-West, School of Medicine - FAMED, Federal University of Mato Grosso do Sul, State of Mato Grosso do Sul, BRA

ARTICLE INFO

Article History:
Received 17th October, 2018
Received in revised form
21st November, 2018
Accepted 02nd December, 2018
Published online 30th January, 2019

Key Words:
Dinamometer; Palmar Force;
Force Variant in the time;
Fingers; Health.

ABSTRACT

The developed electronic biomedical dynamometer was able to measure palmar grip strength and varying forces over time in people whose physical capacity ranges from 0 N up to 1400 N. The mechanical structure is composed of two cylindrical PVC rods, two steel supports, one finger backing, other backing for the palm of the hand and a dynamometric ring containing resistive extensometers. The mechanical structure is composed of two cylindrical PVC rods, where two steel supports are connected, two backings being one for the palm and one for the fingers of the hand, besides having a dynamometric ring where resistive extensometers were bonded. The application of forces by the fingers and by palm of the hand on the backings stretches the steel wire that causes the stretching of the dynamometric ring and produces a corresponding electric signal. This signal is subjected to the signal conditioning circuit for treatment and production of DC electric signal which is digitized by the data acquisition board which sends the signal to the microcomputer containing computational interface that was developed with the Labview software for plotting of graphics, showing the behavior of the forces, indicating maximum and minimum points, being important in the health area.

Citation: Fernanda Guerreiro de Paula, Josivaldo G. Silva, Andrés Batista Cheung and Isabella Fenner Rondon. 2019. "Electronic biomedical dynamometer for measurement, analysis and registration of palmar force and force information in time", *International Journal of Development Research*, 9, (01), 25028-25032.

INTRODUCTION

The human hand is considered one of the most complex organs of the body being composed of nerves, tendons, tissues and bones that in combined form have several purposes: as a prehensile organ it is capable of both applying force, holding and manipulating delicate objects; as a tactile organ it relates the organism to the environment; being important for verbal communication (SANTOS, 2009). Thus, the hand performs diverse activities ranging from delicate and precise movements, such as writing or playing an instrument, to tasks that require strength and power. Is through the hand that we can relate to the external environment, interacting with everything and everyone around us (KAEMPF, 2014).

However, the hand can be affected by injuries and diseases that generate disruption and physical and work limitations in people affected.In view of the foregoing, it is necessary to develop technology that is capable of measuring the strength of the palmar grip strength and variant force over time in order to obtain accurate and objective information that allows the physician to make a correct diagnosis about the presence, severity of diseases or injuries that reach the hand and also monitor the recovery of the affected person. The biomedical dynamometer can be used to monitor the effectiveness of surgeries and also quantify the decrease of the pre-insensitive force over time due to the worsening of the health problem. In general this equipment is of high cost which makes difficult to acquire by health professionals. In view of the above is necessary to develop a versatile electronic biomedical dynamometer capable of measuring the intensities of grip

---

Corresponding author*: **Josivaldo G. Silva,

forces in the 0 to 1400 N range, which is affordable for acquisition by medical clinics and hospitals and can therefore be used by professionals in health clinics and hospitals.

Theoretical Foundations

The fundamental element in the equipment is the dynamometric ring whose layout is shown in Figure (1). The dynamometric ring is constantly subjected to the traction force (***F***) due to the fact that it is attached by steel wires. The greater the traction force produced in the steel wire, the greater the strain () occurring in the region where the resistives extensometers are bonded.

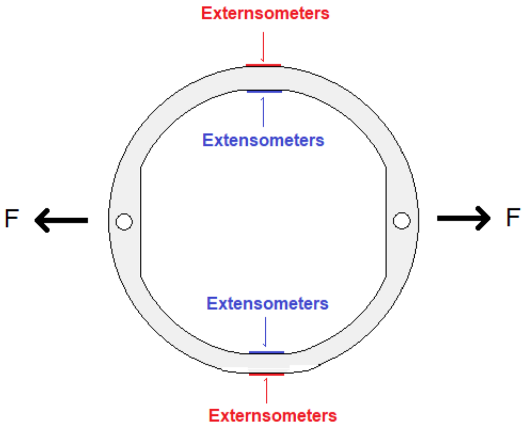

Figure 1. Dynamometric ring
Fonte: Autor.

The resulting strain by each extensometer external to the dynamometric ring is defined by equation (1).

$$\varepsilon(F,t) = -\varepsilon_1(F) \;+\; \varepsilon_2(t) \qquad (1)$$

Being,

$\varepsilon_1(F)$: Strain generated by F;

$\varepsilon_2(t)$: Strain generated by temperature t.

While the strain $\varepsilon(F,t)$ by each extensometer internal to the dynamometric ring is defined by the equation (2).

$$\varepsilon(F,t) = \varepsilon_1(F) \;+\; \varepsilon_2(t) \qquad (2)$$

The Wheatstone Bridge connection shown in Figure (2) allows to obtain the output voltage response (V_0) using four extensometers as shown in equation (3).

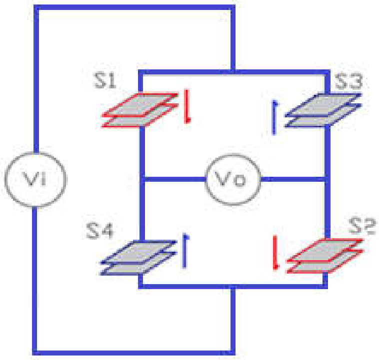

Figure 2.Wheatstone Bridge Connection. Source: Author

$$V_0 = \frac{V_i}{2}\Delta\varepsilon \qquad (3)$$

Being,

V_i:Wheatstone Bridge sinusoidal voltage supply;
V_0:Wheatstone Bridge sinusoidal voltage response;
$\Delta\varepsilon$: Variation of strain resulting from the extensometers.
However equation (4) shows the relationship between $\Delta\varepsilon$ and ΔF.

$$\Delta\varepsilon = \frac{\Delta F}{AE} \qquad (4)$$

Being;

ΔF: Variation of traction force;
A: Cross-sectional area;
E: Young Module.

Being: $\boldsymbol{k} = \frac{V_i}{2AE}$

k:constant.

Finally, we obtain equation (5).

$$V_0 = k\Delta F \qquad (5)$$

MATERIALS AND METHODS

The project of this biomedical dynamometer resulted in the patent deposit in the Brazil, at the National Institute of Industrial Property (INPI) under the number BR 1020170266249. This research was developed in the Biomedical Engineering and Assistive Technology laboratory (ENGBIO) of the Federal University of Mato Grosso do Sul - UFMS being characterized as explanatory and direct. Figure (3) shows the technological development of two cylindrical and identical rods (1) that started with the use of polyvinyl chloride (PVC), as this material is considered to be of low acquisition cost, easy machining and very light. The two rods (1) were constructed containing 30.0 cm in length and 1.0 inch (2.54 cm) in internal diameter, with spiral threads (2) being made along the length of the stems in order to allow the other stems parts of the mechanical structure.

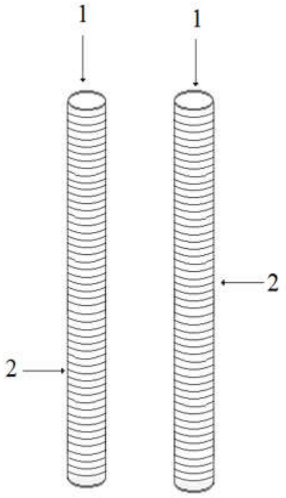

Figure 3. PVC rods. Source: Author

Figure (4) shows the lower nuts (3) and the upper nuts (3) used to secure the left-hand socket (7) and also the right-hand socket (7) which support the lower suport (4) in both the rods (1).This lower suport (4) has a linear shape and was made of stainless steel due to its high mechanical resistance and also due to the fact that it does not oxidize when in contact with human skin. In the lower support (4) a screw (6) was used to fix a lower backing (5) which was manufactured in acrylic because it has a low acquisition cost, easily machined, allows cleaning and supports the palm of the hand or fingers. Both, the lower support (4) and the lower backing (5) have been developed to allow the application of force in the range of 0 to 1400 N. Another relevant factor is that the lower backing (5) can be replaced by another backing whose models are adequate and more ergonomic the person, considering the presence of lesions, deformities in the fingers or in the palm of the hand.

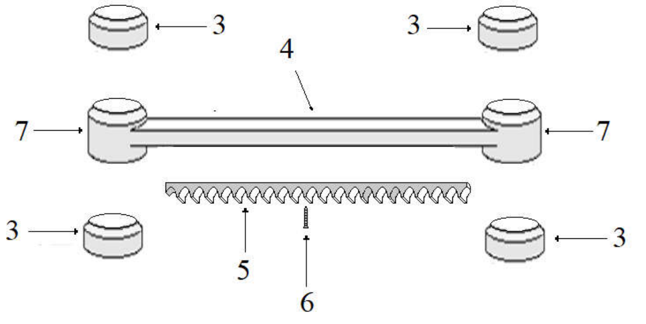

Figure 4. Nuts, grooves, lower support and lower backing Source: Author

Figure (5) shows the lower nuts (3) and also the upper nuts (3) which have been used to secure the left hand socket (8) and the right hand socket (8) which support the upper holder (11), on both rods (1). The steel wire (10) is used to join both the sokets(8) and thus to support the upper support (11) and the dynamometric ring (12).

A screw (6) was used on the upper support (11) to fix an upper backing (9) which was manufactured in acrylic and allows to support the fingers of the hand. In addition, this backing (9) can be replaced by other support models whose formats are ergonomic and consider the presence of lesions or deformities in the fingers. The upper support (11), steel wire (10) and upper backing (9) have been developed to allow application of force in the range of 0 to 1400 N. In addition, the upper backing(9) can be replaced by other support models whose formats are ergonomic and consider the presence of lesions, deformities in the fingers or in the own palm of the hand.

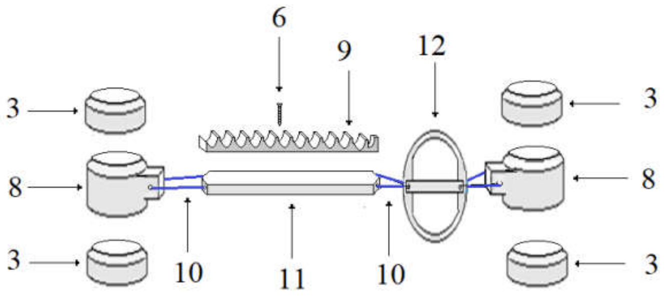

Figure 5. Nuts, grooves, upper support and upperbacking. Source: Author

Figure (6) shows the dynamometric ring (12) developed to withstand applied forces ranging from 0 to 300 N, generally from children. This low limit of strength aims to maximize the sensitivity of the dynamometer in case it is used by children in the 0 to 12 year age group. This dynamometric ring (12) has an external diameter of 7 cm and a thickness of 1.5 cm in which both linear extensometers of the WK - LE - 060PB - 350 (Micro Measurements) model were glued on both the outer surface and the internal surface. linked at Wheatstone Bridge. This ring dynamometer (12) was developed in brass because it is a metal of easy machining and of low acquisition cost. A metal blade (13) has been installed on the dynamometric ring (12) to avoid excessive deformation and to ensure a constant sensitivity for persons whose physical capacity ranges from 300 N to 1400 N. This metal blade (13) was made of stainless steel with 7.0 cm length, 2.0 cm wide and 4.0 mm thick.

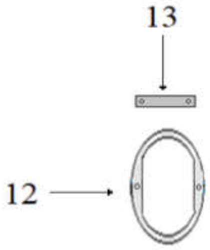

Figure 6. Dynamometric ring Source: Author

Figure (7) shows all the mechanical parts that constitute the mechanical structure of the dinamometer.

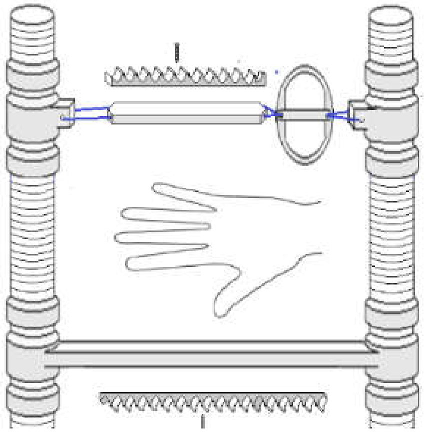

Figure 7. Mechanical structure of the dynamometer.Source: Author

Figure (8) shows the blocks that make up the biomedical dynamometer.

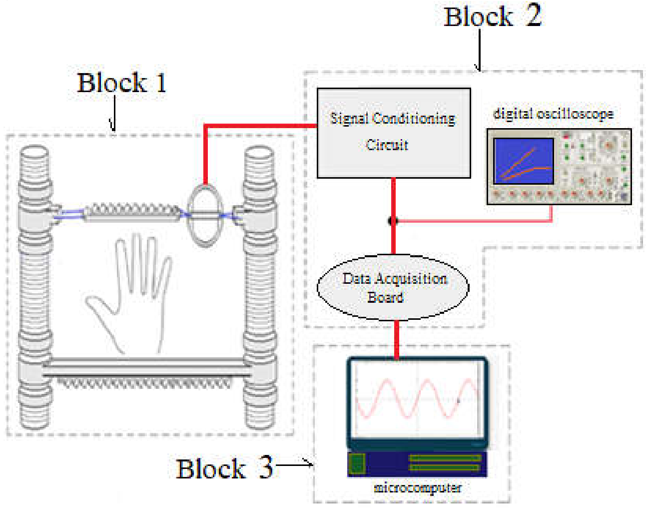

Figure 8. Biomedical dynamometer Source: Author

Table 1. Measurements with addition (R_{ii}) of masses and with the removal of masses (R_i).Source: Autor.

Mass (kg)	Response (V)									
	R11	R1	R22	R2	R33	R3	R44	R4	Vm	S.D
0	0	0	0	0	0	0	0	0	0	0
20	2.29	2.28	2.29	2.29	2.29	2.28	2.29	2.29	2.29	0.01
40	4.51	4.5	4.52	4.52	4.52	4.51	4.51	4.51	4,51.	0.14
60	6.86	6.85	6.87	6.86	6.86	6.86	6.86	6.85	6.86	0.17
80	9.14	9.13	9.14	9.13	9.13	9.14	9.13	9.13	9.13	0.17
100	11.43	11.42	11.43	11.43	11.41	11.41	11.41	11.42	11.42	0.24
120	13.71	13.71	13.71	13.71	13.71	13.71	13.71	13.71	13.71	0
140	16	16	16	15.99	16	16	16	16	16	0

In block 1, when the fingers in opposition to the palm of hand apply gripping forces or varying forces over time in the upper backing (9) and also in the lower backing (5), the extensometers deform and generate electrical intensity-related signal of applied force. This electric signal whose intensity varies from 0 to 10 mV contains low frequency noises of the order of 60 Hz, 120 Hz or 180 Hz which is sent to the input of the signal conditioning circuit contained in block 2. In the signal conditioning circuit, the electrical signal in conjunction with the noise is amplified 10 times, and then this noise is eliminated by means of a bandpass filter with initial cutoff frequency of 15 kHz and final cut-off frequency of 19 kHz with a bandwidth of 4 kHz. In the next phase the electrical signal is subjected to a peak detector with the objective of generating a DC electric signal whose intensity is related to the force applied in the backings(5) and (9). An adjustable 0-32 V and 5 A digital voltage source Mps-3005a (Minipa) was used to power the signal conditioning circuit and a model 54603 B (HP) two-channel digital oscilloscope connected at the output of the conditioning circuit to monitor the treated electrical signal. The DC electrical signal of the peak detector is subjected to a data acquisition card (Exp-rtd16 model) which converts this analog signal into a digital signal and in block 3 is then sent to the microcomputer (Optiplex model 3060) with the objective of to perform processing through a computer interface that has been developed with Labview software to plot behavior charts, generate analyzes over time, obtain fast and slow components of muscle force, and produce information that aids in medical diagnosis and can be stored in a database.

RESULTS

Table 1 shows thedynamometer responses withthecalibration: a) hangstandardizedmasses in the0to 1400 N range on a basketplacedontheupperbacking (9) and b) gradually remove eachmassofthebasketuntil it returnsto 0 N.

The calculations involving the measurements were obtained by equation (6) and equation (7).

$$V_m = \frac{\sum_1^8 R_i}{N} \qquad (6)$$

Being V_m: average and N: number of measurements.

$$S.D = \frac{\Sigma\sqrt{(R_i - V_m)^2}}{N-1} \qquad (7)$$

Being ***S.D***: standard deviation.

Hysteresis refers to the difference between two measured values for the same mass, depending on the direction. Equation (8) shows how to calculate the hysteresis.

$$\%hysteresis = \frac{100MOD}{FSO}$$

Being *MOD*: Maximum response difference for the same input e *FSO*: End-of-scale response.

The maximum hysteresis obtained was 0.9%.

The measured resolution was 0.12 N being defined as the smallest change in the measured value at which the system is able to detect. The correlation coefficient of the line was 0.9999. Figure (9) shows the calibration of the dynamometer that was initially performed by placing standardized masses of 20 kg in the 0 to 140 kg range in a basket that was hung in the upper backing (9). In the next step, each 20 kg mass was gradually withdrawn from the basket hanging on the upper backing (9) until it returned to zero. Since the mass of the basket itself was not considered due to zeroing of the signal conditioning circuit.

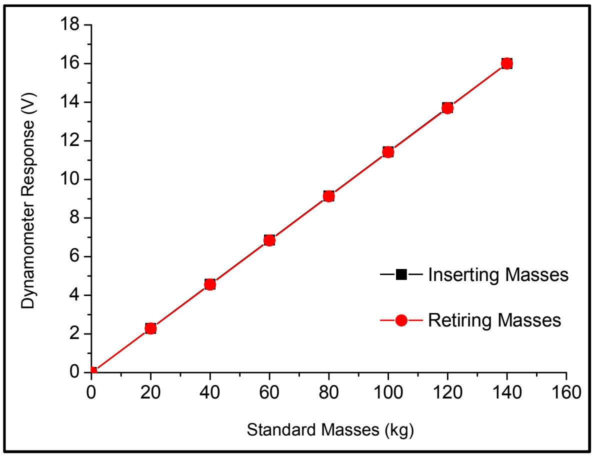

Figure 9. Response with calibration. Source: Author

Figure (10) shows the response time of the dynamometer. The dynamic response of the dynamometer was evaluated by abruptly withdrawing a mass of 80 kg from the basket to measure the time of descent. This time shows the response of the dynamometer when it reaches 63% of the value of the regime and this time measured was 0.27 s.

(6)

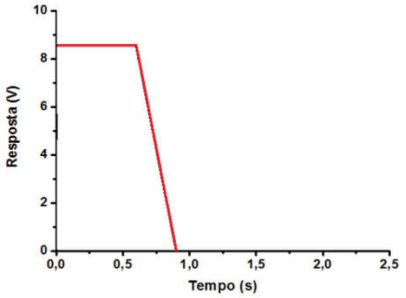

Figure 10. Dynamometer response time. Source: Author

Figure (11) shows the dynamic test with the hand by varying the intensity of the force appliedby a fingeratrandom.

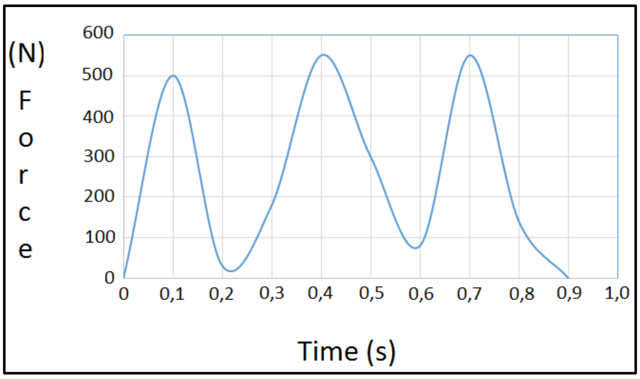

Figure 11. Dynamic test. Source: Author

DISCUSSION

To ensure that the resistive extensometers used had the highest sensitivity, was important to ensure that the bonding of the resistives extensometers occurred in the longitudinal direction of the dynamometric ring. In addition, to eliminate the undesirable effect of the temperature (*t*) on the response voltage (V_0) of the Wheatstone Bridge was necessary that all the extensometers had the same dimensions and were from the same manufacturer. Another important factor was the use of steel wire (10), which mechanically connected the dynamometric ring (12) to the two PVC rods and eliminated the undesirable twisted moment effect on dynamometric ring.

Conclusion

The results obtained show a linearity with correlation coefficient of 0.9999 in the response with a maximum standard deviation of 0.24 and a maximum response of 16.0 V to 1400 N of gripping force. Finally. The project of this biomedical dynamometer resulted in the patent deposit in the Brazil, at the National Institute of Industrial Property (INPI) under the number BR 1020170266249. In addition, this dynamometer has an affordable development cost because it has part of the mechanical structure of PVC and its results were very promising. It can be stated that the equipment presented has great potential for its application in the health area, mainly Physiotherapy and Orthopedics.

Acknowledgements

The National Council of Scientific and Technological Development - CNPq for the financial support in the development of this research. And finally, everyone who contributed to the accomplishment of this work, whether directly or indirectly, is registered here, thank you very much!

REFERENCES

SANTOS, E. A. 2009. BiomedicalDynamometer for Functional Hand Evaluations. Masters dissertation. UNESP, Ilha Solteira.

KAEMPF, R. A.ImportanceofHands. 2014. Available in: <http://www.ricardokaempf. com.br/a-importancia-das-maos>. Access in: 13 de jan. de 2017.

****