Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 6, June 2021: 842- 849

Design and fabrication of a system to measure grip force in fingers

Pramod Narayana A [a], Abhishek Pinninti [b], E Vijayaragavan [c]

[a,b,c]Biomechanics Lab, Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattankulathur 603203, Tamil Nadu, India
Corresponding author: vijayare@srmist.edu.in, aa1359@srmist.edu.in, aa9747@srmist.edu.in

Abstract

Finger grip strength plays a key role in hand ergonomics. The grip force of fingers can also define our overall health and muscular endurance. Modern ways to measure grip strength is electrically by using sensors. Force and Pressure sensors are the main and efficient sensors to measure the grip force in fingers. In this paper, Force Sensitive Resistor (FSR) called Flexi force sensors is used to measure finger grip force. The resistance in the sensor changes when pressure is applied on it. This change in resistance is used to measure finger grip force. A glove type device is developed with FSR's placed on the fingertips of index finger and thumb finger. These sensors are interfaced with Arduino and connected to mobile phone via Bluetooth. Twenty subjects from the age group of 20 - 50 are taken to measure finger grip force. Finger grip force is measured by asking the subjects to hold an ATM card. This gives lower extremity of finger strength. This lower extremity of finger grip gives force required to hold a delicate object. These readings are helpful in developing robotic hands which are used in delicate and complex medical operations

Keywords: Finger grip, Force sensors, Grip strength

1. Introduction

Finger grip strength measure is used in sports and medicine to monitor health like upper body strength and to find muscular endurance [1]. The finger grip force is used to find grip force of prosthetic hands for physically disabled [2]. Finger grip strength is also used to develop robotic which work in sensitive works like manufacturing delicate materials and medical operations which include high precision of the grip [3]. Finger ergonomics is widely evolving topic in field of ergonomics, as fingers are the crucial body part to do any type of work. Finger grip strength can be found between lower and upper extremities depending on the type of work and measurement. High and impulse loading conditions of grip on any object gives upper extremity of the grip strength. This measured to find the health condition and upper body strength of a person. Lower extremity is found to sensitivity of a work or a holding object for a required work. This measurement of lower extremity of finger grip strength should be done very carefully and precisely. Measurement with high precision has been an important part in any measuring system. Measurement of finger grip with high precision even with little touch between any two fingers is required in various fields.

A wide range of techniques available to measure finger grip strength. Dynamometer is the well-known measuring instrument to measure finger grip strength. Jamar dynamometer is one mechanical way to find grip strength. The dynamometer got advanced from analog scale to digital scale [1,4].The dynamometers gives the measure of maximum strength of the grip under impulsive loading conditions. It is not sensitive to touch. Sensors are used to develop a measuring system or equipment to find finger grip strength and sensitive to touch. A new type of multi-axis dynamometer is developed to pressure and direction of force applied using senor [5].An enormous range of touch sensors are used to measure force in finger grip [6]. In Force sensitive resistors, When force or pressure is applied on sensor, the sensor gets deformed and area of the conductive material decreases. This results in change in resistance of the sensor, which then taken as measurement of applied force [7]. Another resistive sensors called strain sensor is used to measure grip force using angle between the fingers. Strain sensor is used to measure the angle of bend of the finger folding called flexion and extension. When the

strain sensor is attached to finger, during cycles of flexion and extension the sensor gets strained. The deformation induced in the strain sensor and changes the resistance signals in the sensor. Larger bending means larger change in resistance and vice versa. These signals are taken as measuring signals and degree of fingers bent can be found. This flexion and extension of fingers plays a significant role in measuring finger grip force [8]. Pieoelectric and Triboelectric are two similar type of sensors used to measure change in pressure, which can be employed in finger grip measurement [6]. When the piezoelectric material is affected by the external force or external deformation in a certain direction, it produces electric polarization, resulting in opposite bound charges on the two surfaces. After the external force was removed, the polarization disappeared, forming the voltage difference. Triboelectric sensors will generate charge after friction or contact under pressure. After release, the sensors are separated from each other to generate voltage difference, thus converting mechanical signals into electrical signal. Like piezoelectric sensors, triboelectric sensors produce electrical signals only when they are in contact and separated. Therefore, most triboelectric sensors are more suitable for dynamic sensing. Capacitive sensors are also used to measure change in force on them. In plate capacitor, applied force changes the distance between the plates of the capacitor, in turn which changes the dielectric of air between the plates. Capacitive sensors are used to measure small deflections. They have advantage of high sensitivity and spatial [9]. In this paper, Force Resistive sensors are used to develop a glove type measuring device which is used to mesure grip force in fingers. The results can be used to set a reference grip force of fingers in simple holding conditions.

As Robots are taking over all the complex works in every field, robotic hands which work in agricultural field must have a ideal grip force for holding delicate plants and leaves for inspection. The resultant grip force value from this paper helps the robotic hand to hold the agricultural products without damage and slipage. The same concept is used in future medical field, where robotic arms are performing complex surgeries and many other fields.

2. Methodology

To measure the grip force in fingers, only index finger and thumb finger are taken into consideration [10]. Grip force between these two fingers is found by asking the user to hold an ATM card with these two fingers. As holding an ATM card does not require much force, this method is used to find the grip force in lower extremities. The lower extremities of grip force gives an ideal and reference values for robotic hand to work on. The grip force is taken from healthy adults as it gives accurate and precise grip force values.

2.1. Design Methodology

The Force Resistive senosrs are employed in developing a glove type measuring device [11,12]. Two FSR's called flexi force sensors A301 are placed on finger tips of index and thumb finger [13]. As shown in **Figure.1** sensor on index finger is slightly placed on to left side of finger and sensor on thumb finger is slightly placed to right of the finger as these are the pressure points while holding an ATM card. The force sensors are interfaced with Arduino UNO. The arduino board and whole circuitry is attached on top of the glove as shown in **Figure.2**.

Figure 1. A301 Flexi force sensors on finger tips of index and thumb finger of a glove.

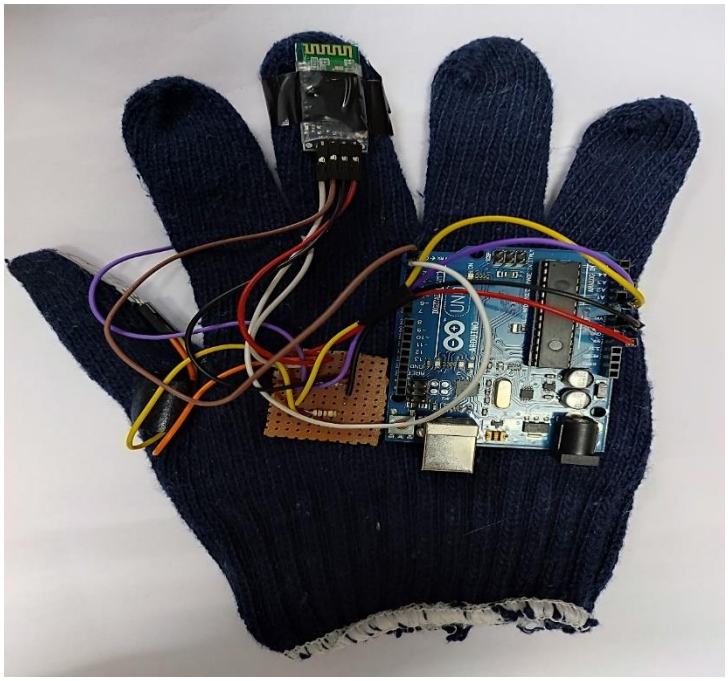

Figure.2 Circuitry on top of the Glove.

2.3 Materials and circuitry

The Device consists of a pair of A301 Flexi force sensors, Arduino UNO, Bluetooth module Hc05, pair of 10k ohm resistors, 9v battery for power supply and a few jumper wires.

2.3.1 Flexi Force sensor

Flexi force sensor is a force sensitive resistor whose resistance changes on application of force or pressure. The FlexiForce sensor acts as a force sensing resistor in an electrical circuit. When the force sensor is unloaded, its resistance is extremely high. When a force is applied to the sensor, there is a proportional decrease in resistance. This decrease in resistance taken force applied. A pair of Flexi force sensors are shown in **Figure.3**.

Figure.3 A301 Flexi Force Sensors.

Properties of A301 Flexi force sensors are

Linearity (Error): < ±3% of Full Scale (Line drawn from 0 to 50% load)

Repeatability: < ±2.5% (Conditioned Sensor, 80% of Full Force Applied)

Hysteresis: < 4.5 % of Full Scale (Conditioned Sensor, 80% of Full Force Applied)

Drift: <5% / logarithmic time (Constant Load of 25 lb (111 N))

Response Time: < 5 µsec (Time required for the sensor to respond to an input force; Impact load – recorded on Oscilloscope)

Operating Temperature: -40°C – 60°C (-40°F – 140°F)

* Force reading change per degree of temperature change = 0.36%/ºC (±0.2%/ºF)

This sensor is interfaced with Arduino uno to have desired output. One end of the FSR is connected to 5v pin of Arduino, the other end is connected to analog pin and to a 10k ohm resistor which is grounded. As shown in **Figure.4** Flexi force sensor and the 10k resistor makes a voltage divider, this way for different forces or pressure values we will get different voltages. From this voltage variation which is due to the force or weight, we can calculate the weight in pounds or kgs.

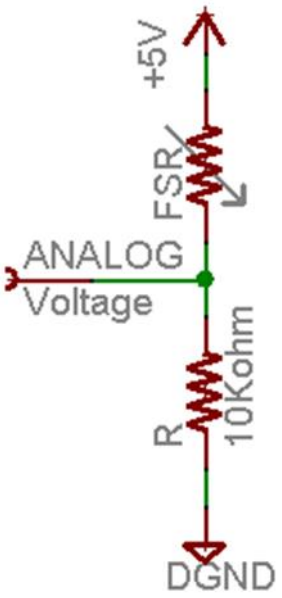

Figure.4 FSR circuit diagram.

2.3.2. Bluetooth module

Bluetooth module HC05 is used to transfer data from Arduino to mobile phone or any Bluetooth enabled device. As shown in **Figure.5** HC05 has four output pins power supply, ground, RX and TX. Power is supplied to HC05 from 5v pin of Arduino, RX of HC05 is connected to TX of Arduino, TX of HC05 connected to RX of Arduino and the other pin is grounded.

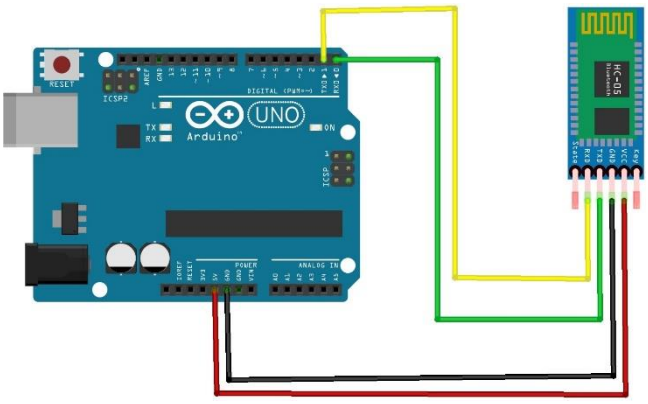

Figure.5 HC05 interfaced with Arduino.

An app is developed using MIT app developer for android phone to display readings in the mobile phone via Bluetooth. The app is created simple with a Bluetooth symbol to check for available Bluetooth device and space to display finger grip force in Newtons.

2.3.3 Glove Type Device

The whole circuitry is placed on top of the glove as shown in Figure.2. The schematic circuit of the measuring device is shown in **Figure.6**.

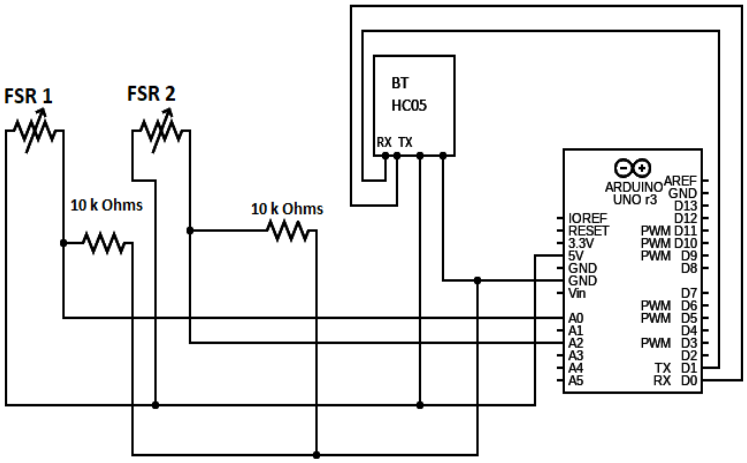

Figure.6 Schematic circuit of grip force measure glove.

3. Experiment

Finger grip force measuring glove is fully developed. The glove gets power from 9V battery which is attached at the wrist of the glove. The device is initially calibrated with a load cell. A load cell of range 0 – 10kg is fixed on a table horizontally for calibration purpose. The user holds the load cell on one end with two fingers tips, where FSR's are placed. The output from the load cell is observed and the output values from FSR's are converted to newtons. The calibration of device is shown in **Figure.7**.

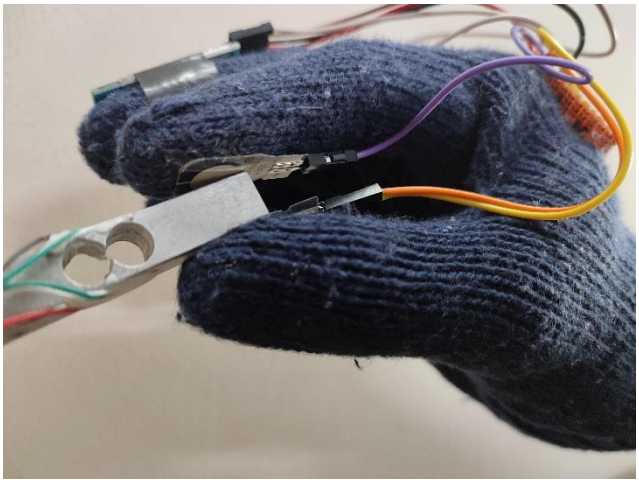

Figure.7 Experimental setup of calibration of finger grip force measuring glove.

The main experimental objective is to find grip force in fingers while holding an ATM card. This grip force gives the value of minimum force required to hold an object. For this, the experiment is done on 20 subjects from age group of 20 to 50 years. The subjects are asked to hold an ATM card with index and thumb fingers as shown in **Figure.8** [14]. The readings of grip force between the fingers are noted from the mobile phone as shown in **Figure.9**. Four trails are done on each subject and average of the four trails is considered as grip force of the subject. The values of grip force between index and thumb finger on holding an ATM card is tabulated as shown in **Table.1**.

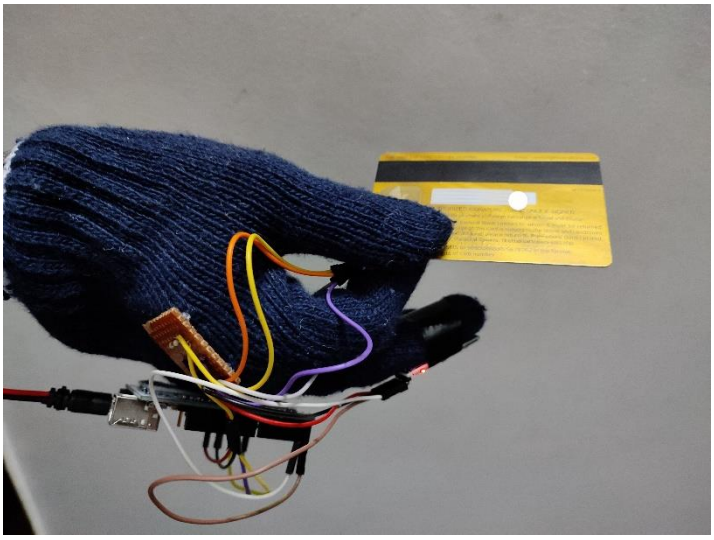

Figure.8 Measuring Grip force in fingers while holding an ATM card.

Figure.9 Grip force values displayed in mobile phone

Subjects	Age (Years)	Finger grip force, F (Newtons)				Finger grip force, F (Newtons) avg
		Trial 1	Trial 2	Trial 3	Trial 4	
Subject 1	20	0.4	0.7	0.3	0.5	0.475
Subject 2	21	0.6	0.4	0.5	0.3	0.450
Subject 3	22	0.7	0.5	0.5	0.6	0.575
Subject 4	23	0.5	0.3	0.2	0.3	0.325
Subject 5	24	0.4	0.7	0.2	0.3	0.400
Subject 6	25	0.1	0.4	0.5	0.4	0.350
Subject 7	26	0.4	0.5	0.7	0.8	0.600
Subject 8	27	0.6	0.7	0.5	0.5	0.575
Subject 9	28	0.5	0.5	0.2	0.4	0.400
Subject 10	30	0.6	0.5	0.7	0.5	0.575
Subject 11	33	0.5	0.4	0.3	0.5	0.425
Subject 12	34	0.3	0.3	0.5	0.4	0.375
Subject 13	35	0.7	0.6	0.5	0.5	0.575
Subject 14	37	0.2	0.2	0.3	0.4	0.275
Subject 15	40	0.3	0.2	0.1	0.3	0.225
Subject 16	43	0.2	0.4	0.5	0.4	0.375

Subject 17	45	0.3	0.5	0.4	0.3	0.375
Subject 18	46	0.5	0.5	0.3	0.3	0.400
Subject 19	47	0.4	0.3	0.4	0.5	0.400
Subject 20	50	1.0	0.9	1.1	0.8	0.950

Table.1 Finger Grip Force values of 20 subjects.

4. Result and Discussion

The average grip force values of the subjects are observed. The highest grip force is **0.950N** and the lowest grip force is **0.225N**. On taking mean value of all the average grip force values, a grip force of **0.455N** is observed and it is considered as the ideal grip force between index and thumb finger of people aged between 20-50 years. A graph is plotted between age and grip force and interpreted for the results and understanding as shown in **Figure.1.**

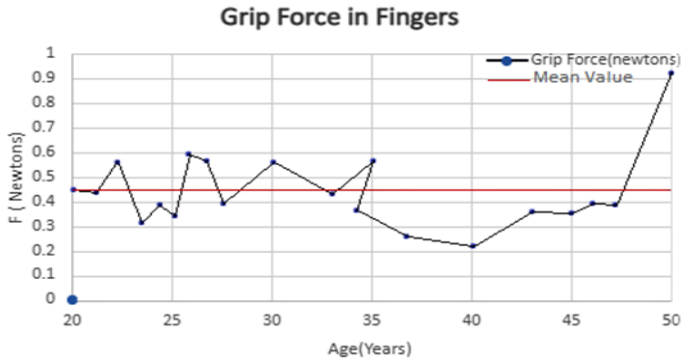

Figure.10 Age vs Grip Force Graph.

From the graph, it can be interpreted that the grip force in fingers does not depends on age and depends on an individual. There is a spike graph at 50years, as the subject older and we can interpret that the grip force people after 50years may increase. The reason might be that older people tends to hold object tightly, as they may do not have confidence to hold it with less force. This is the main reason we limited the age range to 50 years. All the readings are taken from healthy adults, who are in working age group. This value be set as an ideal value of grip force for holding simpler objects like ATM card. On holding an object below safer lower limit value of 0.225, the object might slip form the fingers.

The value of grip force in fingers obtained can be used as a reference value in manufacturing of robotic hands which are used in agricultural and medical fields, where the robotic hands have to deal with sensitive materials and has to do complex operations. With this grip force the robotic hand can hold light and simple objects with perfect grip.

5. Conclusion

In modern health-conscious world, knowing about health conditions and muscular endurance is important. Finding grip force in fingers helps to know about our forearm strength which tells the muscular endurance of the body. Modern advancement in technology involves various sensors which are used in every field. Likewise, Grip force in fingers can be found by using sensors called Flexi force sensor which is a Force sensitive resistor, whose resistance changes on application of force or pressure. A pair of A301 Flexi force sensors are used to develop a finger grip force measuring Glove. The finger grip force measuring Glove is connected to Bluetooth to make the glove portable and wireless. On observing grip force in fingers value of 20 subjects of age ranging from 20 years to 50 years, we can conclude that the mean grip force of fingers in 0.455N. So, this value of grip force in fingers can be used as a reference value in designing and manufacturing of robotic hands, as it is taken from healthy subjects and can be considered as safe grip force to hold an object with two fingers. The newly developed finger grip force measuring glove can be used to monitor health of a human by measuring their grip force in fingers.

Acknowledgements

Special thanks to Dr. E. Vijayaraghavan for guiding and supporting us through the project. The 20 subjects were not forced or harmed. We did the experimentation on them with their full acknowledgement and willingness

References

[1] Sasaki1, Koji Makino, Akimoto Nimura, Shiro Suzuki, Tomoyuki Kuroiwa, Takafumi Koyama, Atsushi Okawa1, Hidetsugu Terada and Koji Fujita. Assessment of grip-motion characteristics in carpal tunnel syndrome patients using a novel finger grip dynamometer system. Journal of Orthopedic Surgery and Research (2020); 15:245.

[2] . Nur'Aqilah Zainuddina, Nur Farahin Anuara, Ahmad Luqman Mansura, Nur Izzati Mohd Fauzia, Wan Fazlida Hanima and Sukreen Hana Herman. Resistive-based Sensor System for Prosthetic Fingers Application. Procedia Computer Science 76 (2015) 323 – 329.

[3] Michel de Mathelin, Florent Nageotte, Philippe Zanne and Birgitta Dresp-Langley. Sensors for Expert Grip Force Profiling: Towards Benchmarking Manual Control of a Robotic Device for Surgical Tool Movements. Sensors 21 October 2019.

[4] J Methot, SJ Chinchalkar, RS Richards. Contribution of the ulnar digits to grip strength. Can J Plast Surg 2010; 18(1):e10-e14.

[5] C.B. Irwin, J.D Towles and R.G. Radwin. Development and Application of a Multi-Axis Dynamometer for Measuring Grip Force. Ergonomics. 2013 December; 56(12).

[6] Ming Cheng, Guotao Zhu, Feng Zhang, Wen-lai Tang, Shi Jianping, Ji-quan Yang, Li-ya Zhu. A review of flexible force sensors for human health monitoring. Journal of Advanced Research 26 (2020) 53–68.

[7] E R Komi, J R Roberts and S J Rothberg. Evaluation of thin, flexible sensors for time-resolved grip force measurement. Journal of Mechanical Engineering Science 1989-1996 (vols 203-210) January 2008.

[8] Park JW, Kim T, Kim D, Hong Y, Gong HS (2019). Measurement of finger joint angle using stretchable carbon nanotube strain sensor. PLoS ONE 14(11)

[9] Wook Chang, Kee Eung Kim, Hyunjeong Lee Joon Kee Cho, Byung Seok Soh, Jung Hyun Shim Gyunghye Yang, Sung-Jung Cho and Joonah Park. Recognition of Grip-Patterns by Using Capacitive Touch Sensors. IEEE ISIE 2006, July 9-12, 2006.

[10] Yeongyu Park and Joonbum Bae. A Three-dimensional Finger Motion Measurement System of a Thumb and an Index Finger Without a Calibration Process. Sensors 30 January 2020.

[11] . Junghoon Park, Pilwon Heo, Jung Kim and Youngjin Na. A Finger Grip Force Sensor with an Open-Pad Structure for Glove-Type Assistive Devices. Sensors 18 December 2019.

[12] Yong-Ku Kong, Brian D.Lowe. Optimal cylindrical handle diameter for grip force tasks. International Journal of Industrial Ergonomics 35 (2005) 495–507.

[13] Nazrul H. Adnan, Khairunizam Wan and Shahriman AB. Accurate Measurement of the Force Sensor for Intermediate and Proximal Phalanges of Index Finger. International Journal of Computer Applications (0975 – 8887) Volume 45– No.15, May 2012.

[14] Lingling Sun, Jiayao Fan, Guangzhong Song , Shaofang Cai, Chunhong Fan, Yaohong Zhong, Yingjun Li. Exposure to phthalates is associated with grip strength in US adults. Ecotoxicology and Environmental Safety 209 (2021) 111787.

[15] Alice Wichelhau, Christoph Harms1, Julia Neumann, Steffen Ziegler, Günther Kundt, Karl Josef Prommersberger, Thomas Mittlmeier1 and Marion Mühldorfer-Fodor. Parameters influencing hand grip strength measured with the manugraphy system.. BMC Musculoskeletal Disorders (2018);19:54.

[16] Y. N. TURRELL, F.-X. LI, and A. M. WING. Estimating the minimum grip force required when grasping objects under impulsive loading conditions. Behavior Research Methods, Instruments, & Computers 2001, 33 (1), 38-45