International Journal of Service Science, Management, Engineering, and Technology
Volume 13 • Issue 1

An Adaptive Neural-Fuzzy Inference System for Prediction of Muscle Strength of Farmers in India:

An Approach for E-Healthcare 4.0 Prevention and Analysis

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ABSTRACT

In the present study, 13 anthropometric hand dimensions, hand grip strength, push strength, and pull strength of 90 male farmers of Odisha in India were statistically analyzed, and then fuzzy logic toolbox of MATLAB version 2010 was used in order to create the fuzzy inference system (FIS) using ANFIS. The mean hand grip strength with standard deviation was found to be 255.21 N ± 75.46. The average push strength in standing posture for farmers was found to be 193.12 N ± 76.12, whereas pull strength in standing posture was 200.59 N ± 64.02. Very high correlation coefficient (i.e., 0.977, 0.994, and 0.990) was obtained between "hand length and hand grip strength," "hand breadth with thumb and push strength," and "hand length and pull strength," respectively. Finally, from the obtained ANFIS models for the prediction of muscle strength, it was concluded that ANFIS could well predict the farmers' muscle strength with minimum errors. This will help to evaluate muscle capabilities to avoid musculoskeletal disorders and in ergonomic design of tools and equipment as a healthcare initiative.

KEYWORDS

ANFIS, Farmers, Hand Grip Strength, Odisha, Pull Strength, Push Strength, Regression Analysis

INTRODUCTION

The grip strength of hand is very important and essential in the daily lives. The strength of muscles for the peoples engaged in farming are most considerably used and of essential significance for working diverse equipment and gadget in agricultural activities. A static strength database of capability and constraints of farmers necessitates helping in the design of agricultural tools and equipment. Such that

DOI: 10.4018/IJSSMET.297497
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the design & force requirements for different farming activities can be matched with the job demand & capability of farmers, and also the acceptability of tools and equipment will be more increasing the overall performance. The ordinary techniques for cultivating results in physical issues like lungs issue because of introduction to residue, and musculoskeletal issue. Additionally, outrageous climate conditions, and substantial remaining tasks at hand give them early seniority, bones & muscles issues. As a result to achieve better effectiveness of execution in addition to improve profitability of the overall farmers in the rural areas, it is a basic requirement to plan the tools and equipment by considering the farmers' capacity and breaking points. The configuration of tools & equipment ought to have the option to give increasingly human solace, good quality, more yield focused and ready to decrease the musculoskeletal injury reducing ability. While designing the equipment the operator's biological needs are taken into consideration. The muscular strength of farmers is most considerably used in most of the agricultural activities. Therefore to help in the design of agricultural tools & equipment, there is a need to build up a database of static quality abilities and constraints of farmers. Such that the design & force requirements for different farming activities can be matched with the job demand & capability of farmers by enhancing their overall performance. Muscle strength has been revealed to be essential for physically execution of work (Brill et al., 2000) and fitness (Bohannon, 2008; Ortega et al., 2008). Mishra et al. (2018a) have suggested to improve the tool and equipment designs, and to improve the layout of workplaces in addition to the work practices, for infeasibility in the cases of eliminating the recurrence of work. The design process is greatly influenced and augmented by the measurement of physical characteristics. Moreover, the use of sensors for the measurement process provides quick and accurate information. The Jamar dynamometer has been suggested as the gold-standard for measuring grip strength of hand (Fess, 1992). Different studies have been carried out to examine which position of Jamar dynamometer (Firrell and Crain, 1996; Trampisch et al., 2012) and grip span for obtaining maximum grip strength of hand (Espana-Romero et al., 2008; Ruiz et al., 2002; Ruiz et al., 2006) in selected populations.

BACKGROUND

In the literature, a number of studies are made in the measurement and assessment of physical characteristics of human body. The measurement of strength of hand grip was reported to be influenced by body and upper limb positions (Fong and Ng, 2001; Mathiowetz et al., 1984). The strength of the muscles of hand influences its ability for adjusting itself to hold an object (Trzaskoma and Trzaskoma, 2001), as well as the hand's skeletal size of muscle (Peters et al., 2011; Shahida et al., 2015). Grip strength has been regarded as a possible case for overall body strength prediction of both the sexual categories (Tietjen-Smith et al., 2006; Barlow et al., 2014). Combining both the intrinsic as well as extrinsic hand muscles help in grip generation (Abe et al., 2015). Strength of handgrip can be affected by various factors. For instance, epidemiological assessments have revealed the handgrip strength and age, to have a curvilinear relationship with each other (Ekşioğlu, 2016; Mathiowetz et al., 1985; Werle et al., 2009), linearly increases with BMI, weight, and height (Shyamal and Yadav, 2009; Jürimäe et al., 2009; Wu et al., 2009), and less in females than males (Ekşioğlu, 2016; Kamarul et al., 2006; Li et al., 2010), as well as greater in dominant hand (Schlüssel et al., 2008; Werle et al., 2009). Some of the anthropometric hand dimensions were reported to be correlated to grip strength, such as width of palm, length of hand, and circumference of forearm, respectively (Anakwe et al., 2007; Günther et al., 2008; Shim et al., 2013). Strength of hand grip increasing with the hand size is an existing general assumption (Peters et al., 2011; Shahida et al., 2015). If the hand grip strength reduces i.e. lesser than 30 kg for men and 20 kg for women, then it is a sarcopenia indication (Cruz-Jentoft et al., 2010). Yadav et al. (2010) have presented the strength data parameters of both male as well as female labors of Saurashtra region in Gujarat (India). The average pushing strength for both male as well as female labors with both hands was found as 248.2 N and 171.0 N, and pulling strength was found as 232.3 N and 141.7 N, in standing posture. This can be used for the design of wheel-hoe, manually operated pushing and pulling equipment, and lawn mower. Similarly in sitting posture, the maximum value of pulling strength for right hand considering the 5th percentile of both male & female labors were 68.7 N and 54.4 N, and for 95th percentile of both male & female labors were 124.2 N and 77.0 N, respectively helpful in the design of joystick, handle lever, workplace design, gearshift lever etc. Further, it was recommended to carry out such extensive research in other regions of country for male & female farmers together to ensure safety and efficiency in the design / modification of farming tools & equipments. Tiwari et al. (2010) have made a survey on 920 persons from different regions of Madhya Pradesh (India). The total number of males was 604 and females were 316. For 5th percentile of males, the pushing and pulling strength were found as 167.0 N and 163.5 N, while for females it was found as 124.4 N and 134.4 N, correspondingly. Also, it was further recommended to use these values in the design of manually operated agricultural tools and equipments, and for manual materials handling actions. Agrawal et al. (2010) have analyzed male and female farmers together from 20 districts of Madhya Pradesh in India, and found that the pushing/pulling strength of male farmers was higher than those of female farmers. In standing posture, for male farmers the average pushing strength with both hands was found as 242.4 $\pm$ 56.4 N, and pulling strength was found as 231.0 $\pm$ 42.5 N. And for female farmers the average pushing strength with both hands was found as 175.5 $\pm$ 33.9 N and pulling strength was found as 159.4 $\pm$ 42.9 N, respectively. The pushing and pulling strength for 5th percentile of males were found as 149.7 and 161.2 N, while for females it was found as 119.7 and 88.8 N, respectively. The grip strength of hand in addition to some of the dimensions of hand may differ in athletes having handgrip movements with an opponent or object, as compared to non-athletes (Fallahi and Jadidian, 2011). Chen et al. (2011) have examined 30 males in Taiwanese to decide the greatest level isometric pushing and pulling qualities under 16 unique statures and 4 handle-foot flat separations. This investigation demonstrated that the isometric push and force qualities estimated on a virtual frictional floor condition for example by utilizing a low-rubbing flooring ($\mu = 0.48$) in Taiwanese hyper-markets were altogether lower than utilizing a high footing deck. Hao-Lun et al. (2012) have conducted the handgrip test of 65 right handed subjects in Chiayi, for four different age groups i.e. in age of 55-60 (n=22), in age of 61-65 (n=16), in age of 66-70 (n=14), and for over 71 years old (n=13). It was found that due to the application of force with independent arm & repetitive actions, the exhaustion & injury in muscles were produced easily. They have likewise suggested that activity and resistive preparation can improve bulk and bone thickness. Lee et al. (2012) have studied the grip strength of dominant hands in elderly Koreans and found that strength in grip was autonomously connected with age and stature in men and women together, and besides with BMI in men. Loss of autonomy, increased need for care and increased mortality are related to weak muscle strength. Also, the reduced grip strength was used for prediction of decline in health, as well as for measuring sarcopenia (Cooper et al., 2011). Wibowo et al. (2013) have concluded that the Javanese male farmers were more grounded close by hold power and crush by two hands, when contrasted with the Madurese males of East Java in Indonesia. Additionally, the Madurese male farmers were discovered more grounded in middle draw in bowed position with palm looking down and palm looking up, arm lift, and shoulder lift. Female farmers of Javanese were likewise more grounded than Madurese female farmers in middle draw in bowed position, while palm looking down and palm looking up, arm lift, bear lift, hand hold strength, and squeeze in hand. The grip strength of hand was found to be influenced by the upper limb pain for individuals in both genders and males have comparatively higher muscle strengths when compared to females (Wagner et al., 2014). For older adults, both knee extension strength and handgrip were considered as important predictors of functional performance (Martien et al., 2014).Patel et al. (2015) have measured isometric strength data of 130 male along with 70 female farmers of Kamrup region in Assam and found that there was a significant reduction in handgrip strength by increment in age, also the handgrip strength of females were found considerably lower than the males.Grip strength has been reported as a simpler, inexpensive and extensively-used clinical measure for strength of the muscles (Walker-Bone et al., 2016). Ong et al. (2017) have studied the older adults in Singapore and found relatively weak hand grip strength compared to other countries. Also lesser waist circumference, and more height and weight, were found independently related with more hand grip strength in females only. Length of hand, age & circumference of forearm were reported to be impacted significantly by grip strength of hand in Saudi Arabian healthy adults (Alahmari et al., 2017). Pushing and pulling activities are very common in farming activities such as during land preparation, weeding, and harvesting etc. when carried out manually. And even when these activities are performed with the aid of some machinery, then also some sort of manual pushing and pulling efforts are required by the farmers. In the state of Odisha in India, ten farm women were considered to analyze the drudgery level while using plain as well as serrated sickles for cutting crops, and by using an improved serrated sickle based on their anthropometric measurements. The improved serrated sickle was revealed as reducing the drudgery level in comparison to the plain as well as the existing serrated sickle (Mishra et al., 2018b). Pratama and Setiati (2018) have found a significant correlation of -0.568 between functional mobility using the timed up and go test, and grip strength of hand in a study of elderly patients.

Different algorithms and architectures have found a number of applications in diverse field of research in the recent years. For instance, the use of deep-learning with the use of computers has recently been introduced in agriculture (Loey et al., 2020). The use of cloud-computing has also gained a greater interest in the last few years (Hedaia et al., 2020). Sharma et al. (2020) have proposed a "MapReduce (MR)" approach for performing edge-detection of satellite-images by the use of the nature-inspired "Artificial Bee Colony" algorithm. Deena et al. (2020) have used "natural language processing (NLP)" techniques to generate the multi-choice questions dynamically. Raja et al. (2020) have proposed the "Fuzzy Extraction, Resolving, and Clustering (FERC)" architecture that uses fuzzy-logic techniques for the identification and clustering of uncertain textual spatial-reference. Dif and Elberrichi (2020) have used "inception-v3 convolutional neural-network architecture", six histopathological-source datasets, and four target-sets as base-modules and revealed the importance of the pre-trained histopathological-models compared to the ImageNet-model. The use of particle swarm optimized k-means cluster help in achieving a higher-accuracy in comparison to the traditional clustering-technique (Elfergany and Adl, 2020). However, the basis of ANFIS is driven from the approach of fuzzy modeling and the fuzzy inference system (FIS) permits extracting the model from the data of input or output (Zadeh, 1973; Krueger et al. 2011). Jang (1993) has first proposed the adaptive neural-fuzzy inference system (ANFIS) application. ANFIS has been defined as a rule based system with three elements, such as membership function of input as well as output variables, fuzzy rules, and the characteristics of output & system outcomes, respectively. And also learning & generalization of the training data are possible with the use of ANFIS (Krueger et al., 2011). A feed forward neural network structure, having each layer as a component of neural-fuzzy system is associated with ANFIS (Fahimifard et al., 2009). Serge (2001) has depicted the strength of ANFIS as its capability to execute linguistic concepts and to find nonlinear relationships between input and output. The learning methods such as propagation and hybrid are normally used for the specification of the input & output relationships in ANFIS, and also for the determination of the optimum membership functions distribution. Acharya and Kundu (2007) have used neuro-fuzzy tools in segmentation of image. Both the propagation along with least square method combination represents the hybrid system (Übeyli, 2008). The change of parameters in relation to membership functions takes place in learning and the gradient vector facilitates the estimation of the parameters. For reducing errors, an optimized procedure can be performed based on the gradient vector obtained for parameters adjustment (Singh et al., 2010; Singh et al., 2008). The handgrip strength of patients was collected and by the use of neuro-fuzzy technique, it was distinguished from the normal persons. The classification accuracy of normal persons was observed as 90%, while for pathological patients was 75%, respectively (Seng et al., 2010). Similarly, by the use of ANFIS classifier, the classifications of normal and pathological were obtained as 90% and 75%, respectively (Hafiz et al., 2006). Ahmad et al. (2010) have worked on linear least squares and neuro-fuzzy (ANFIS) model considering the adult Malaysia occupants, for relating age, weight & height with hand grip strength. Moreover, superiority of the ANFIS model was reported in comparison to the linear model, as inputs and output were non-linearly associated with each other. Based on the neural network (NN) and regression approach, various studies have already been done in the field of prediction of hand grip strength as well as other parameters. For instance, to analyze the hand arm vibration exposure during operation resulting in the loss of hand grip strength, 204 hand held grass cutter workers were considered. It was observed that for neural network, the performance index of regression were better fit considering the right and left hands altogether in comparison to multiple regressions, and also the neural network model was obtained more superior to the linear model (Ali et al., 2015). Mathur et al. (2016) have implemented ANFIS for predicting temperature of in-socket residual limb. Sahin and Erol (2017) have applied NN approach and ANFIS model to forecast the attendance rate at games of soccer, and found better performance in NN approach than ANFIS model. The attributes of cantaloupe, potato, and garlic while drying by the use of dryer at convective hot air, were predicted using "ANFIS" as well as "Artificial Neural Network (ANN)", and ANFIS method was found to have the higher ability in the evaluation of all output in comparison to ANN (Kaveh et al., 2018). Utama et al. (2018) have used ANFIS, the incorporation of neural network along with fuzzy theory, as decision support tool to make a decision for going or not going on projects in overseas construction.

Apart from the above literature on hand grip strength prediction, the ANFIS models has been successfully used by different researchers as a predicting tool in agricultural sector also, such as for prediction of the grain yield of irrigated wheat, in Iran (Naderloo et al., 2012; Khoshnevisan et al., 2014), for farming data estimation (Liu et al., 2008), to gauge the exporting rural item incomes (Mohaddes et al., 2015), and for the enthusiastic and financial demonstration of lentil and chickpea generation in Iran (Elhami et al., 2016), and so forth. From the above literature, it was clear that the muscle strength of farmers play a vital role in farming activities and although a number of studies have been done in the application of neuro-fuzzy models in agricultural sectors, but it was not yet used to predict the muscle strength. Hence in the present study an attempt was made to use the ANFIS model for the prediction of hand grip strength, pushing and pulling strength of farmers' in Odisha (India), so that due attention can be provided by the farmers while executing their works to avoid the musculoskeletal disorders, and also the design aspects of farm tools and equipment from ergonomic point of view as a health-care initiative.

RESEARCH METHODOLOGY

Subjects

To predict the grip strength of farmers, different regions of Odisha in India was selected having maximum population dependent on agriculture. A total of 90 male farmers between the age groups of 21 to 78 were considered for the survey. It was ensured prior to the selection of farmers, that they are free from any kind of ill health or disease.

Anthropometric Dimensions

As gripping, pulling and pushing activities are mainly performed by hands, hence for the present analysis only hand dimensions were considered. A total of 13 different hand dimensions were measured as illustrated in Table 1 by using commercially available tape with flexibility but non stretch-ability having 1mm of least count, wooden cone, and vernier caliper, respectively. For measuring the hand dimensions, the landmarks as well as nomenclature suggested by Chakrabarti (1997) was followed in this study.

Measurement of Muscle Strength

The strength of hand grip of elderly peoples helps to predict or indicate their health conditions. In addition, the muscle strength in terms strength of hand grip can be evaluated with the use of some

Table 1. The measured hand dimensions in the study

Serial No.	*Dimensions of hand
1.	Length of hand
2.	Length of palm
3.	Length of fist
4.	Length of hand grip
5.	Breadth of hand grip
6.	Breadth of hand with thumb
7.	Breadth of hand without thumb at metacarpal
8.	Depth of finger tip
9.	Breadth of finger tip
10.	Depth of hand at metacarpal
11.	Depth of hand at thumb base
12.	Circumference of fist
13.	Maximum inside diameter of grip

*All dimensions are in cm unless and otherwise mentioned.

standardized and calibrated instruments (Massy-Westropp et al., 2011). Also, Syddall et al. (2003) have recommended the use of hand dynamometers to measure the strength of hand grip. In the present study the strength of hand grip of all the selected male farmers was measured using commercially available Jamar hand dynamometer (Figure 2) having graduation of 1 kg and a range of 0-90 Kg. Similarly, the pushing strength along with the pulling strength of each farmer by their dominant hand was measured by the use of a "Baseline universal 250lb digital push-pull dynamometer" (Figure 3). The test for the strength of hand grip was performed in standing position for the dominant hand only. The subjects were asked for standing in erect positions with their arms to hang downwards, trunk & wrist in neutral positions for providing utmost grip force by hand. In all measurements (for strength of hand grip, pushing strength and pulling strength), in order to avoid fatigue in muscles the replications recorded were thrice with about 3-5 min rest gap in between two trials to the individual farmer. Finally for the subsequent analysis, the average of the two utmost readings was used from all the three trial readings. The stepwise procedure followed in this study was as illustrated in Figure 1.

Data Analysis

Initially, the measured anthropometric hand dimensions, grip strength of hand, pushing strength, and pulling strength were statistically analyzed, and correspondingly the mean value, standard deviation value, 5th & 95th percentile values were calculated. By using Minitab17 version software, the Pearson's correlation coefficient matrix and regression analysis was done. Then, by using ANFIS in the fuzzy logic toolbox of "MATLAB 2010 version" was used in order to create the fuzzy inference system (FIS).

RESULTS AND DISCUSSION

Anthropometric Data

The mean value, standard deviation (SD) value, 5th & 95th percentile values for the measured 13 dimensions of hand by considering 90 male farmers were summarized in Table 2. The percentile values obtained can be used for the new agricultural equipment design, in the modification of the

Figure 1. Stepwise procedure followed

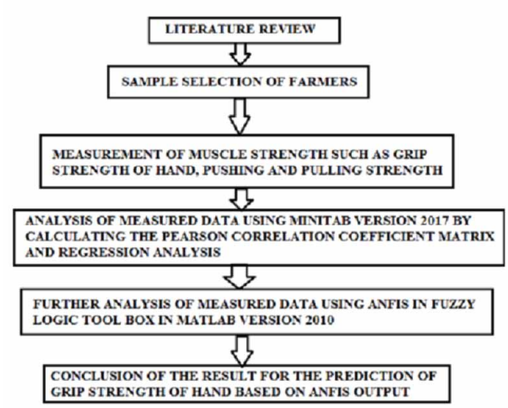


Figure 2. Jamar hand dynamometer

Figure 3. Baseline universal 250lb digital push-pull dynamometer

existing equipment suitable for the farmers need, and also in designing work places. However, the selection of the percentile value by the designer depends on his/her requirements.

Strength of Hand Grip

The explanatory statistics of the measured strength for hand grip were as summarized in Table 3. In the measurement 90 male farmers were considered where 84 (93.33%) farmers were right-handed and 6 (6.67%) farmers were left-handed. For the present analysis the strength of hand grip for only the dominant hand was considered. The mean strength of hand grip with standard deviation was found to be 255.21 N ± 75.46.

Table 2. Anthropometric hand dimensions of farmers (N = 90)

Serial No.	Anthropometric dimensions of hand	Mean	Standard deviation (SD)	5th percentile	95th percentile
1.	Length of hand	17.41	3.12	11.9	22.1
2.	Length of palm	10.50	2.78	8.4	17.1
3.	Length of fist	9.32	1.86	7.3	13.1
4.	Length of hand grip	4.87	1.25	3.5	7.4
5.	Breadth of hand grip	8.89	1.84	6.9	12.9
6.	Breadth of hand with thumb	9.60	1.13	7.8	11.5
7.	Breadth of hand without thumb at metacarpal	7.78	0.96	6.1	8.9
8.	Depth of finger tip	1.25	0.19	1	1.6
9.	Breadth of finger tip	1.42	0.14	1.3	1.6
10.	Depth of hand at metacarpal	2.18	0.68	1.5	3.7
11.	Depth of hand at thumb base	3.93	1.02	2.8	6.1
12.	Circumference of fist	26.51	3.42	22.7	33.9
13.	Maximum inside diameter of grip	4.53	0.61	3.9	5.6

All dimensions are in cm unless and otherwise mentioned.
N = Number of farmers.

Table 3. Strength of hand grip for farmers (N = 90)

Parameter	Mean	Standard deviation (SD)	5th percentile	95th percentile
Strength of hand grip (N)	255.21	75.46	98	372

N = Number of farmers.

Pushing and Pulling Strength

The average pushing strength in the standing position for the selected farmers was found to be 193.12 N ± 76.12, whereas pulling strength in the standing position was 200.59 N ± 64.02 that can be used in design of manually operated pushing and pulling type equipment.

Correlation Analysis

The correlation coefficient value which is in between -1 to 1 depicts the strength of linkage between two variables. A correlation which is positive acts to be a sign of a positive relationship, while a correlation which is negative acts to be a sign of a negative relationship between the variables. The Pearson Correlation coefficients (r) between the measured 13 anthropometric dimensions of hand along with the strength of hand grip, pushing strength as well as the pulling strength for male farmers were as shown in Table 5. In the Minitab17 version software by the use of pearson product moment correlation, the correlation coefficients along with the corresponding p-values for different

Table 4. Pushing and pulling strength of farmers (N = 90)

Parameters	Mean	Standard deviation (SD)	5th percentile	95th percentile
Pushing strength (N)	193.12	76.12	74	318
Pulling strength (N)	200.59	64.02	96	293

N = Number of farmers.

Table 5. Correlation of anthropometric dimensions of hand with strength of hand grip, pushing strength and pulling strength

Serial No.	Anthropometric dimensions of hand	Strength of hand grip		Pushing strength		Pulling strength	
		r	p	r	p	r	p
1.	Length of hand	**0.977****	0.000	**0.993****	0.000	**0.990****	0.000
2.	Length of palm	0.774**	0.000	0.837**	0.000	0.808**	0.000
3.	Length of fist	0.890**	0.000	0.938**	0.000	0.925**	0.000
4.	Length of hand grip	0.863**	0.000	0.921**	0.000	0.904**	0.000
5.	Breadth of hand grip	0.899**	0.000	0.949**	0.000	**0.935****	0.000
6.	Breadth of hand with thumb	**0.967****	0.000	**0.994****	0.000	**0.989****	0.000
7.	Breadth of hand without thumb at metacarpal	**0.961****	0.000	**0.953****	0.000	**0.953****	0.000
8.	Depth of finger tip	**0.939****	0.000	0.938**	0.000	0.926**	0.000
9.	Breadth of finger tip	**0.903****	0.000	0.910**	0.000	0.906**	0.000
10.	Depth of hand at metacarpal	0.871**	0.000	0.945**	0.000	0.930**	0.000
11.	Depth of hand at thumb base	**0.918****	0.000	**0.966****	0.000	**0.949****	0.000
12.	Circumference of fist	**0.921****	0.000	**0.955****	0.000	**0.936****	0.000
13.	Maximum inside diameter of grip	0.883**	0.000	**0.957****	0.000	**0.943****	0.000

**Correlation was significant at P< 0.01 (2-tailed).

parameters were obtained. The correlation coefficient values that were very high i.e. 0.977, 0.994 and 0.990 was obtained between "length of hand and strength of hand grip", "breadth of hand with thumb and pushing strength", and "length of hand and pulling strength", respectively. While, lower correlation coefficient values i.e. 0.774, 0.837 and 0.808 was obtained between "length of palm and strength of hand grip", "length of palm and pushing strength", and "length of palm and pulling strength", respectively. Also, it was observed that all the thirteen measured dimensions of hand were significant at $p<0.01$ (2-tailed).

Regression Analysis

The best fit linear regression equation for the prediction of the strength of hand grip (Y) as in equation (1) was obtained by considering the strength of hand grip as dependent variable and other 7 significant dimensions of hand as independent variables, having the correlation coefficient (r) values of more than 0.9. Also, the linear regression equation for the prediction of the pushing strength (PS) as in equation (2) was obtained by considering the pushing strength as dependent variable and other 6 significant dimensions of hand as independent variables, having correlation coefficient (r) values of more than 0.950. Similarly, the linear regression equation for the prediction of the pulling strength

(PL) as in equation (3) was obtained by considering the pulling strength as dependent variable and other 7 significant dimensions of hand as independent variables, having correlation coefficient (r) values of more than 0.930. It may be noted that as more number of independent variables were found to be significant with high correlation coefficient values, hence for better prediction for strength of muscles, only the independent variables having very high correlation coefficient (r) values were taken into consideration.

Predicted strength of hand grip (Y) of farmers:

$$Y= -202.0+26.59X_1-60.1X_6+41.99X_7+130.6X_8-82.0X_9-36.6X_{11}+12.89X_{12} \quad (1)$$

Predicted pushing strength (PS) of farmers:

$$PS= -220.7+14.53X_1+20.29X_6-2.57X_7+22.10X_{11}-6.98X_{12}+18.45X_{13} \quad (2)$$

Predicted pulling strength (PL) of farmers:

$$PL= -116.8+14.52X_1+6.82X_5+16.26X_6+0.11X_7+11.88X_{11}+11.60X_{12}+23.69X_{13} \quad (3)$$

where:

X_1= Length of hand
X_2= Length of palm
X_3= Length of fist
X_4= Length of hand grip
X_5= Breadth of hand grip
X_6= Breadth of hand with thumb
X_7= Breadth of hand without thumb at metacarpal
X_8= Depth of finger tip
X_9= Breadth of finger tip
X_{10}= Depth of hand at metacarpal
X_{11}= Depth of hand at thumb base
X_{12}= Circumference of fist
X_{13}= Maximum inside diameter of grip

The regression model summary in context with strength of hand grip (R= 97.75%, Adjusted R squared value = 97.56%), in context with pushing strength (R= 99.38%, Adjusted R squared value= 99.34%), and in context with pulling strength (R= 98.79%, Adjusted R squared value= 98.69%), was illustrated separately in Table 6, Table 7 and Table 8, which signifies that the level of prediction is good.

The validation of the regression models from the data collected from 90 male farmers was done using equation (4) for the "standard error of estimation (SEE)" as follows:

Table 6. The Summary Model for Regression Analysis in context with Strength of hand grip

S	R-sq	R-sq (adj.)	R-sq (pred.)
11.7982	97.75%	97.56%	97.09%

Table 7. The Summary Model for Regression Analysis in context with Pushing strength

S	R-sq	R-sq (adj.)	R-sq (pred.)
6.19238	99.38%	97.34%	99.18%

Table 8. The Summary Model for Regression Analysis in context with Pulling strength

S	R-sq	R-sq (adj.)	R-sq (pred.)
7.32441	98.79%	97.69%	98.30%

$$\text{SEE}=\sqrt{\frac{\sum\left(Y-Y1\right)^2}{\left(n-2\right)}} \tag{4}$$

where:

Y= Value observed
Y1= Value predicted
n= Number of scores pairs

The obtained standard error of estimation (SEE) value was found as 10.82 in context with strength of hand grip, as 5.96 in context with pushing strength, and as 6.87 in context with pulling strength after validations, which were small and thus proved the validity of the model.

ANFIS Analysis Output

The total number of inputs was seven including: length of hand, breadth with thumb, breadth of hand without thumb at metacarpal, depth of finger tip, breadth of finger tip, depth of hand at thumb base, and circumference of fist, while the strength of hand grip was considered as the output for the ANFIS model 1 (Figure 4). The most effective and the best adjustment with minimum errors in ANFIS model was ensured by five significant adjustments carried out in the structure of ANFIS network. These settings included the number as well as types of membership functions (triangular, bell-shaped, gaussian, trapezoidal, and sigmoid), output membership function types (constant or linear), methods of optimization (hybrid or back propagation), and the epoch numbers. For the ANFIS model 1, bell-shaped membership function with 100 epochs was considered. Prediction for strength of hand grip, errors, and ANFIS information for ANFIS model 1 were as illustrated in Figure 5, and Figure 6, respectively. It can be seen that ANFIS could well predict the farmers' strength of hand grip with minimum errors.

The total number of inputs was six including: length of hand, breadth of hand with thumb, breadth of hand without thumb at metacarpal, depth of hand at thumb base, circumference of fist, and maximum inside diameter of grip, while the pushing strength was considered as the output for the ANFIS model 2 (Figure 7). Bell-shaped membership function with 100 epochs was considered for better prediction of result. Pushing strength prediction, errors, and ANFIS information for ANFIS model 2 were as illustrated in Figure 8, and Figure 9, respectively. Similarly, the total number of inputs was seven including: length of hand, breadth of hand grip, breadth of hand with thumb, breadth of hand without thumb at metacarpal, depth of hand at thumb base, circumference of fist, and maximum inside diameter of grip, while the pulling strength was considered as the output for

Figure 4. ANFIS model 1

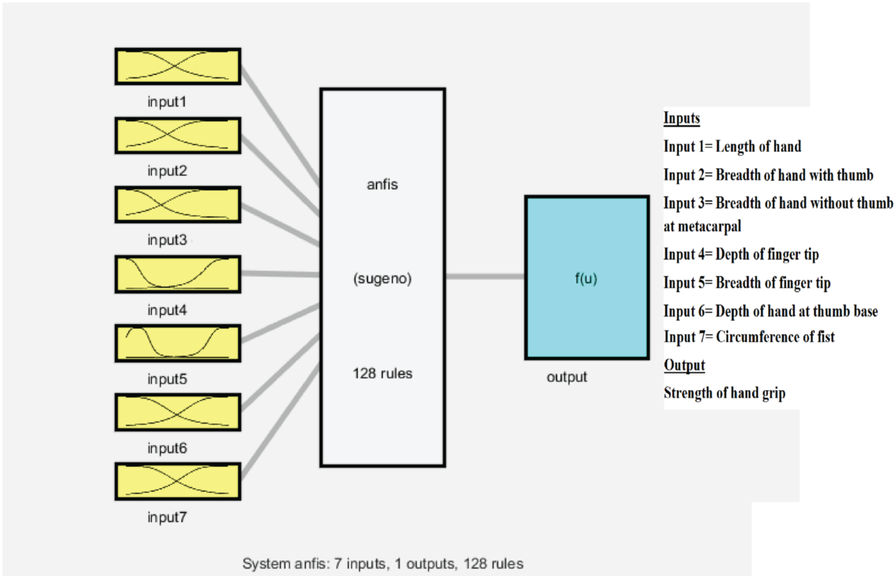
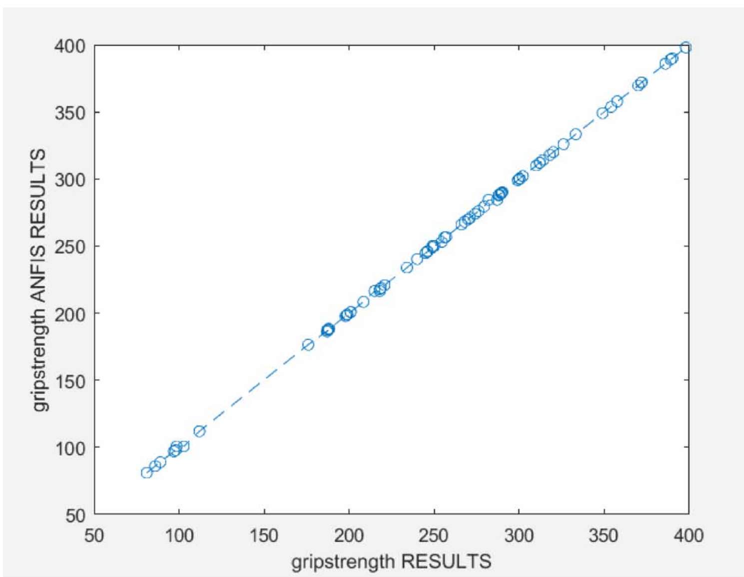


Figure 5. Prediction for strength of hand grip in ANFIS model 1



the ANFIS model 3 (Figure 10). After various adjustments, bell-shaped membership function with 100 epochs was considered for better prediction of result. Prediction of pulling strength, errors, and ANFIS information for ANFIS model 3 were as illustrated in Figure 11, and Figure 12, respectively. It can be seen that ANFIS could well predict the farmers pushing strength as well as pulling strength with minimum errors.

Figure 6. ANFIS model 1 error

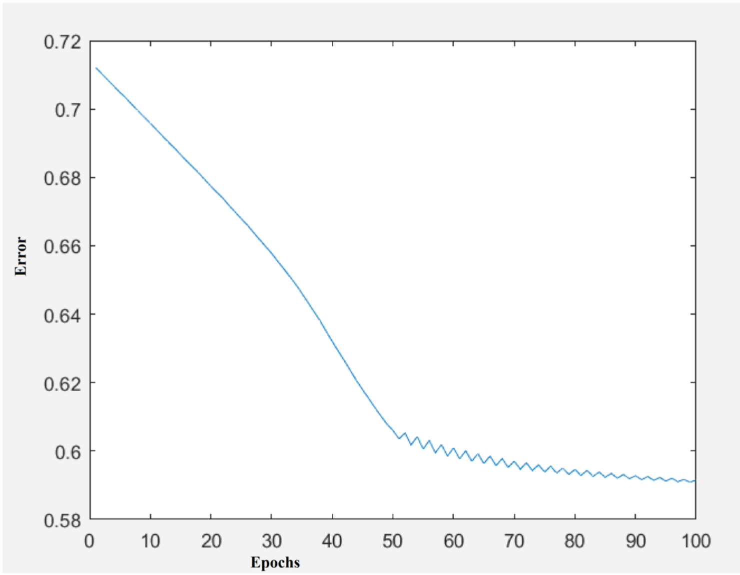
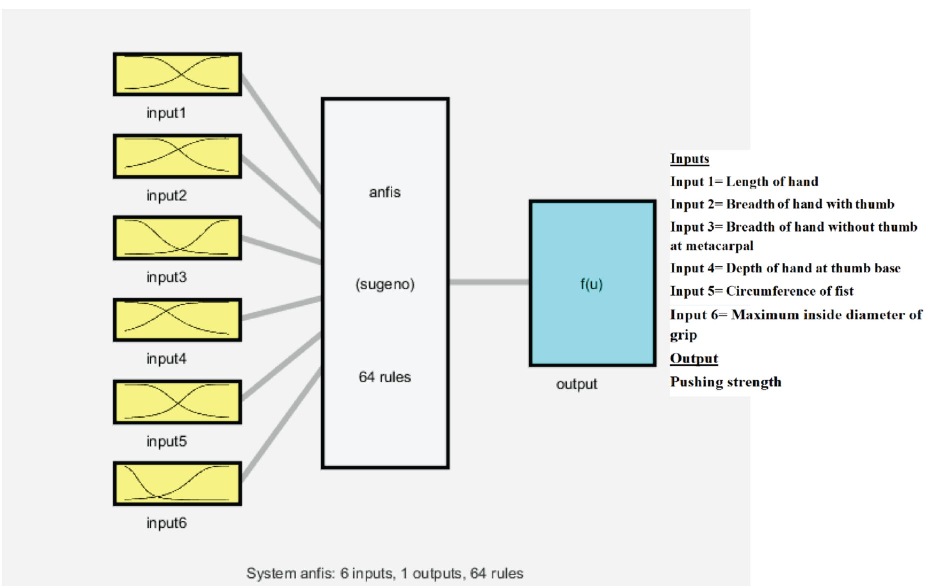


Figure 7. ANFIS model 2



CONCLUSION

In this paper, adaptive neural-fuzzy inference system (ANFIS) was used for the prediction of the strength of hand grip, pushing strength, and pulling strength of farmers of Odisha in India. The measured 13 dimensions of hand of the selected farmers in the present analysis were length of hand, length of palm, length of fist, length of hand grip, breadth of hand grip, breadth of hand with thumb,

Figure 8. Prediction of pushing strength in ANFIS model 2

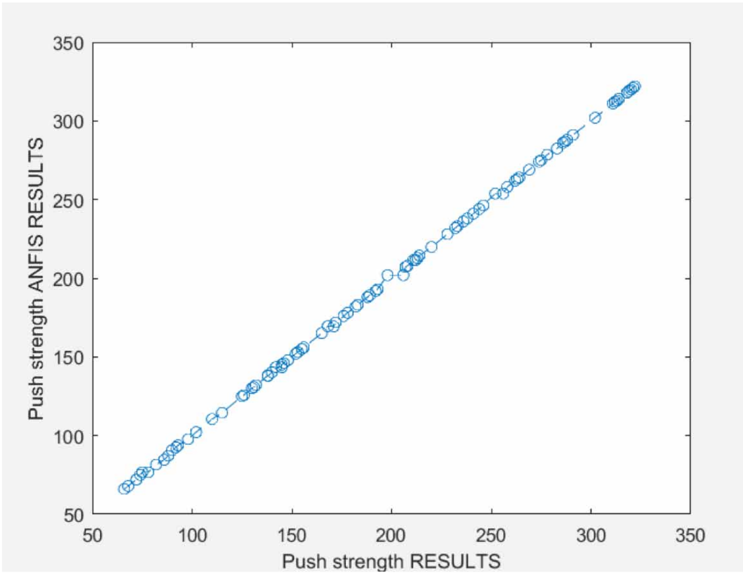
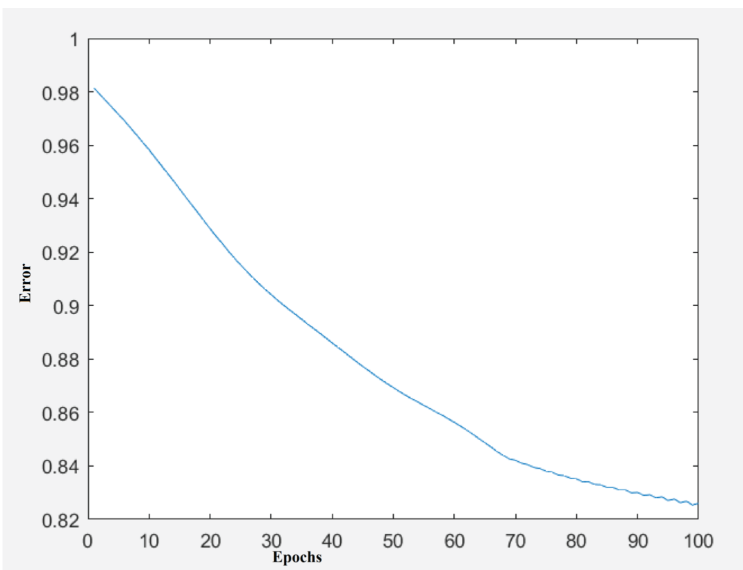


Figure 9. ANFIS model 2 error



breadth of hand without thumb at metacarpal, depth of finger tip, breadth of finger tip, depth of hand at metacarpal, depth of hand at thumb base, circumference of fist, and maximum inside diameter of grip, respectively. As high correlation values were obtained for all the thirteen measured hand dimensions i.e. independent variables, hence for the subsequent regression and ANFIS analysis, only the independent variables with very high correlation coefficient values were considered separately.

Figure 10. ANFIS model 3

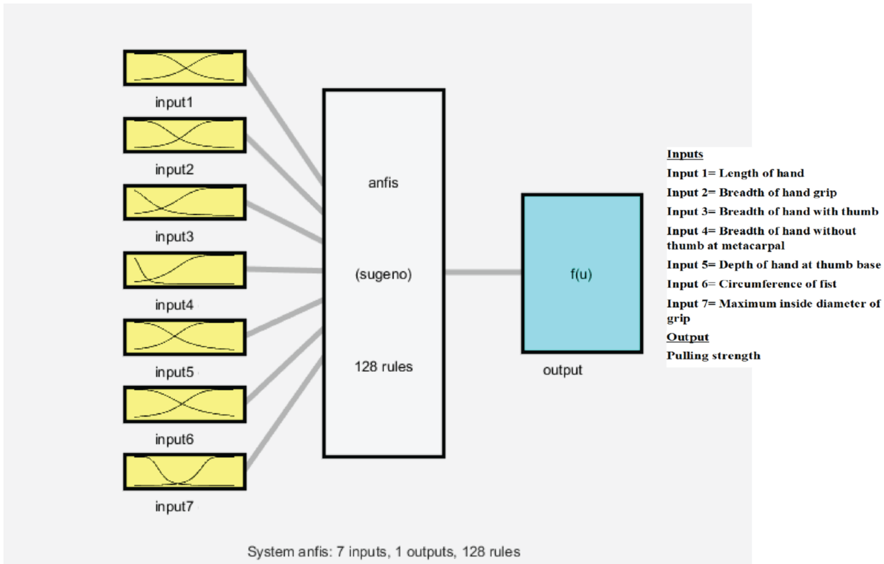
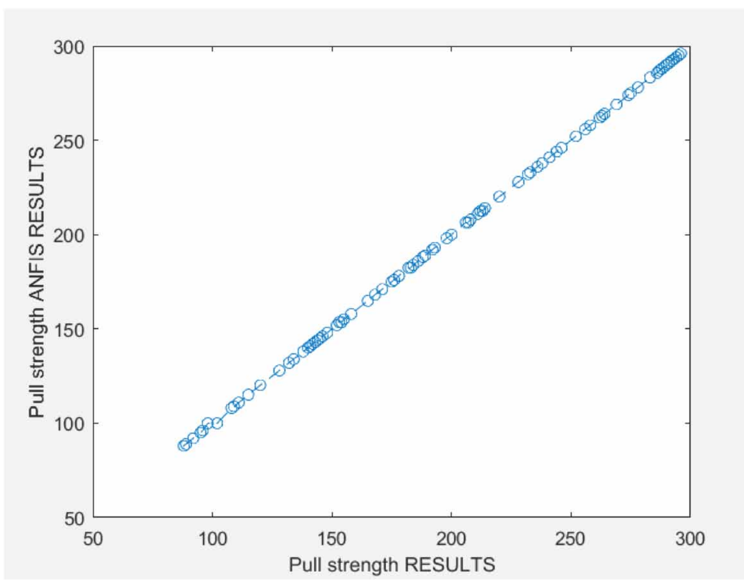
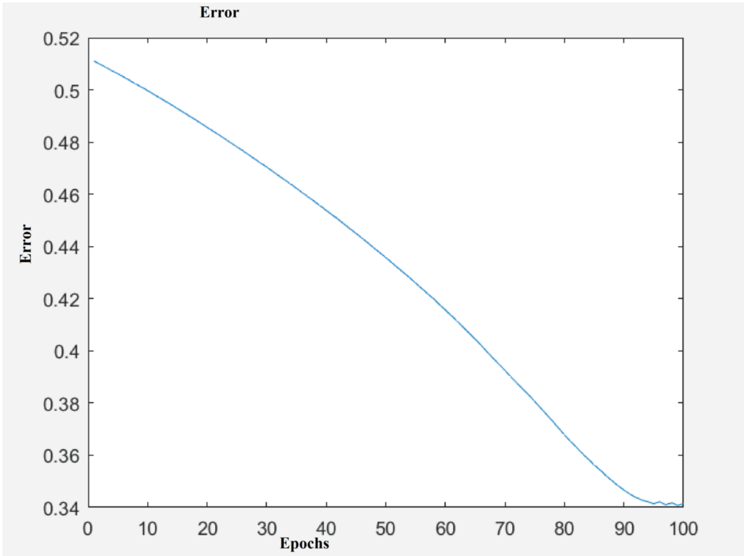


Figure 11. Prediction of pulling strength in ANFIS model 3



Three ANFIS models were generated individually for the prediction of strength of hand grip, pushing strength, and pulling strength of farmers, respectively. The results showed that ANFIS could well predict the farmers' strength of muscles with minimum errors. As only male farmers were considered, hence further studies with the female farmers could be carried out for further analysis with larger sample sizes in order to obtain more significant result.

Figure 12. ANFIS model 3 error



ACKNOWLEDGMENT

The publisher has waived the Open Access Processing fee for this article.

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