A device for assessment of the contractile force of different groups of muscles of upper and lower limbs

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Abstract:

Background: There are no currently reliable devices for the appropriate calculation of the force exhibited by the muscles in different parts of the body. A device is unique in measuring the contractile force of different groups of muscles of the upper and lower limb is invented.

Aim of the work: The aim of this study was to examine of a new device for the assessment of the contractile force of different groups of muscles of upper and lower limbs.

Materials and methods: 270 subjects of both sexes at different age group and different body mass index; 135 athletics and 135 non-athletics were assessed on two sessions 2 weeks apart. To aid implementation we have created a new device with freely available software to extract data of the device in Kg and convert it into newton. The contractile force of different groups of muscles of the upper limb was measured at 2 sessions by 3 professional assessors. Statistical analysis using IBM SPSS software package version 20.0. Quantitative data were described using mean and standard deviation for normally distributed data. Comparison between two independent population were done using independent t-test while more than two population were analyzed F-test (ANOVA) to be used.

Results: Comparison of the contractile force of different groups of muscles of the upper and lower limbs between the 1st and 2nd measurements revealed that there was a highly significant positive correlation, the kappa in all variables was more than 0.70, indicating a high association of the two measurements. The new device has an excellent for most measures of force in athletics and non-athletics at different age groups.

Conclusion: the new device is assessment of the contractile force of different groups of muscles of the upper and lower limbs**.**

Introduction:

Skeletal muscles rarely work by themselves to achieve movements in the body. More often they work in groups to produce precise movements[9]. The muscle that produces any particular movement of the body is known as an agonist or prime mover. The agonist always pairs with an antagonist muscle that produces the opposite effect on the same bones. In addition to the agonist/antagonist pairing, other muscles work to support the movements of the agonist. Synergists are muscles that help to stabilize a movement and reduce extraneous movements. They are usually found in regions near the agonist and often connect to the same bones. Because skeletal muscles move the insertion closer to the immobile origin, fixator muscles assist in movement by holding the origin stable [15].

Two important components of muscle function are; muscle strength which is the peak force that a muscle group can produce and muscle power which is how rapidly that force can be produced [15]. Muscular weakness, as a component of muscle function, is an impairment that is commonly observed in clinical populations and has been widely documented to impact upon physical function[16]. Muscle power has previously been quantified by calculating the rate of force development (RFD), which is calculated by measuring the change in force over a certain period of time (Δ force/Δ time), usually during an isometric contraction [5]. Previous literature assumed that reduced muscle power, commonly associated with old age, may contribute to reduced physical

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function and an increased risk of falls in a range of clinical populations. Assessments of muscle power may be useful in clinical settings for identifying individuals at risk of falls and functional limitations [1].

There are varying methods utilized to calculate RFD from isometric contractions, commonly used methods involve calculating the change in force over the change in time with discrete time intervals from the onset of contraction to 30, 50 or 100ms [13]. Other methods of calculating RFD involve examining successive time intervals (e.g. 5ms) during the initial rise in force to determine the peak RFD across the trial or examining the RFD between percentages of the peak force (e.g. between 30 and 60% of peak force) [4].

laboratory-based dynamometry is used in the assessment of muscle strength and power, but limitation of laboratory-based dynamometers is that they are expensive and difficult preventing their use as a clinically-suitable device for routine patient assessment [8]. Linear position transducers can be used to assess dynamic muscle power however the cost, availability, time-consuming nature, and difficulty of implementation of such assessments may limit their use in clinical settings [3]. This study aimed to determine the concurrent of a new device to assess the contractile force of different groups of muscles of the upper and lower limbs.

Materials and Methods:

Research Methodology:

The researchers used a descriptive approach due to its suitability to the nature of the research.

Participants:

Duration of the study:

The study lasted about seven months in the period from 28/10/2018 to 28/5/2019 distributed as follows:

- The pilot study was conducted from 28/10/2018 to 1/11/2018.
- The first basic study was conducted in the period from 2/11/2018 to 2/3/2019.
- The second basic study was conducted in the period from 3/3/2019 to29/5/2019.

Measurements used:

A. Anthropometric Measurements:

- Measuring the total length of the body to the nearest (cm)
- Measuring weight to nearest (kg)
- Find the Body Mass Index (BMI) Body Mass Index, obtained from the following equation: weight (kg) / square length (meters).

B - Measurements of muscle strength of the upper limb muscles:

- pronation Forearm right / left (Newton).
- supination Forearm right / left (Newton).
- flexion wrist right / left (Newton).
- extension wrist right / left (Newton).
- flexion Elbow Right / left (Newton).
- shoulder Right / left (Newton).

C - Measurements of muscle strength of the lower limb muscles:

- planterflexion Foot Right / left (Newton).
- dorsiflexion Foot Right / left (Newton).
- eversion Foot Right / left (Newton).
- inversion Foot Right / left (Newton).

The pilot Study:

Pilot study was done in the club of the Sports Foundation and Ezz El_Dekheila in Alexandria - Dar Mohammed Ragab for the care of the elderly in Alexandria - the school of Omar Lotfy and Mohammed Korium school in Alexandria from 28/10/2018 to 1/11/2018 with the aim of taking approval from the administrative personnel for the participants in the study sample.

The basic study:

The contractile force of different groups of muscles of 270 subjects of both sexes at different age group and different body mass index; 135 athletics and 135 non-athletics were assessed on two sessions 2 weeks apart. The demographic distribution and BMI of the participants is shown in (table. 1 and 2).

Table (1): Age distribution among the studied groups.

Age	N	Minimum	Maximum	Mean	S.D.
Elderly female	15	75.00	80.00	77.93	1.87
Elderly male	15	75.00	80.00	78.80	1.57
patient female	15	70.00	80.00	74.73	2.15
patient male	15	70.00	80.00	74.67	2.16
Female Students College	15	19.00	20.00	19.53	0.52
male Students College	15	19.00	20.00	19.47	0.52
School Students Female	15	9.00	12.00	10.67	1.11
School Students Male	15	9.00	12.00	10.80	1.21
Female School students	8	13.00	17.00	15.00	1.31
male School students	7	14.00	17.00	16.00	1.15
swimming Female	15	17.00	21.00	19.13	1.25
Swimming Male	15	17.00	21.00	19.13	1.30
Female fencing	15	17.00	21.00	19.27	1.39
male fencing	15	17.00	21.00	19.33	1.50
female Athletics	15	18.00	20.00	19.27	0.80
male Athletics	15	18.00	21.00	19.53	1.13
Female Gymnastics	15	7.00	10.00	8.93	0.88
male Gymnastics	15	8.00	12.00	10.00	1.46
Female Taekwondo	8	13.00	17.00	15.00	1.51
male Taekwondo	7	14.00	17.00	15.29	1.11
Total	270	7.00	80.00	35.82	22.16
ANOVA P value		116.5 0.0001*			

Table (2): BMI distribution among the studied groups.

BMI	N	Minimum	Maximum	Mean	S.D.
Elderly female	15	29.70	33.70	31.90	0.99
Elderly male	15	30.50	34.10	32.04	0.95
Wheel chair female	15	26.10	29.30	27.55	0.79
Wheel chair male	15	26.90	30.10	28.39	0.80
University female Students	15	21.00	24.50	22.99	1.05
University male Students	15	19.80	22.50	21.56	0.70
Female 1ry School Students	15	17.10	19.50	18.13	0.62
Male 1ry School Students	15	16.80	18.40	17.70	0.47
Female 2ry School students	8	21.70	25.90	24.58	1.28
Male 2ry School students	7	21.20	22.90	21.73	0.59
Swimming Females	15	21.20	23.00	21.96	0.45
Swimming Males	15	18.00	18.80	18.49	0.27
Fencing Females	15	21.30	23.80	21.94	0.60
Fencing Males	15	21.80	23.00	22.41	0.34
Athletic Females	15	20.60	22.10	21.24	0.44
Athletic Males	15	21.50	23.30	22.45	0.45
Gymnastic Females	15	16.50	19.20	17.86	0.86
Gymnastic Males	15	17.80	20.40	19.09	0.84
Taekwondo Females	8	24.10	25.90	24.91	0.64
Taekwondo Males	7	20.80	21.70	21.24	0.29
Total	270	16.50	34.10	23.31	3.60
ANOVA P value		201 0.0001*			

Participants were required to have no upper or lower limb injury in the preceding two months that could potentially impact on the assessment of muscle force. This study used t-test while more than two populations were analyzed F-test (ANOVA), whereby participants attended two identical testing sessions. All participants gave written informed consent.

Instrumentations:

To determine BMI we used sensitive balance scale graduated tape. BMI is calculated by taking one's weight (kg) and dividing the square of one's height (m) [19].

The proposed device consists of two metal plates connected through a pivot that allowed both of them to move freely and independently Figure (1). Three parallel springs were placed in between the two plates to support the loading applied from the contraction of muscles as shown in Figure (2). The loading cause compression of the springs that will be in accordance to Hook's law and reliable correlation between loading and displacement could be maintained. The system of springs was connected to an electronic system to monitor the changes resulted from its compression, whereas any micro-changes in the spring length could be detected. Moreover, the body of the metal plates was also attached to resistive electronic sensor to reflect any angle deviations would be produced under the application of the loading. The obtained data were displayed on liquid crystal display (LCD) using custom-written Arduino software and soldered and compactly packed in a plastic casing (20×20 cm^2). For more applicability of the system of measurement, there were two separate antennas, one placed as transmitter from the body of the plates and the other was a wireless receiver at the plastic casing. An illustrative sketch of the main electronic components of the system is shown in Figure (3).

Furthermore, the system was calibrated under known weights to perform load-displacement curve of the system of springs. The calibration was attained by loading the system by weights of 1-25 kg with increment of 1 kg as adapted elsewhere [10, 18]. It is worthy to mention that the calibration was repeated for each loading weight step 10 times and average values were taken for reliable measurements. Taking the advantage of the load-displacement curve to specify an equation to transform the deviation of the plates under loading conditions into force, one can directly convert the readings from the LCD screen into force.

Figure 1: The device with its software.

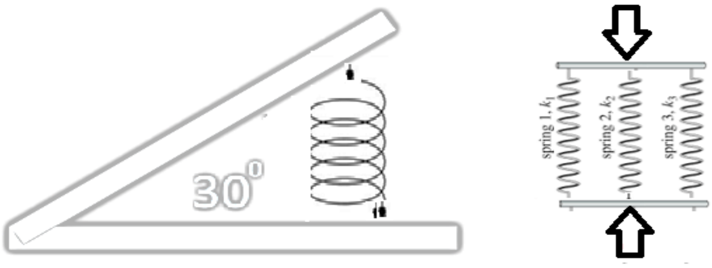

Figure 2: sketch diagram of the two metal plates sandwiching three springs in paralle

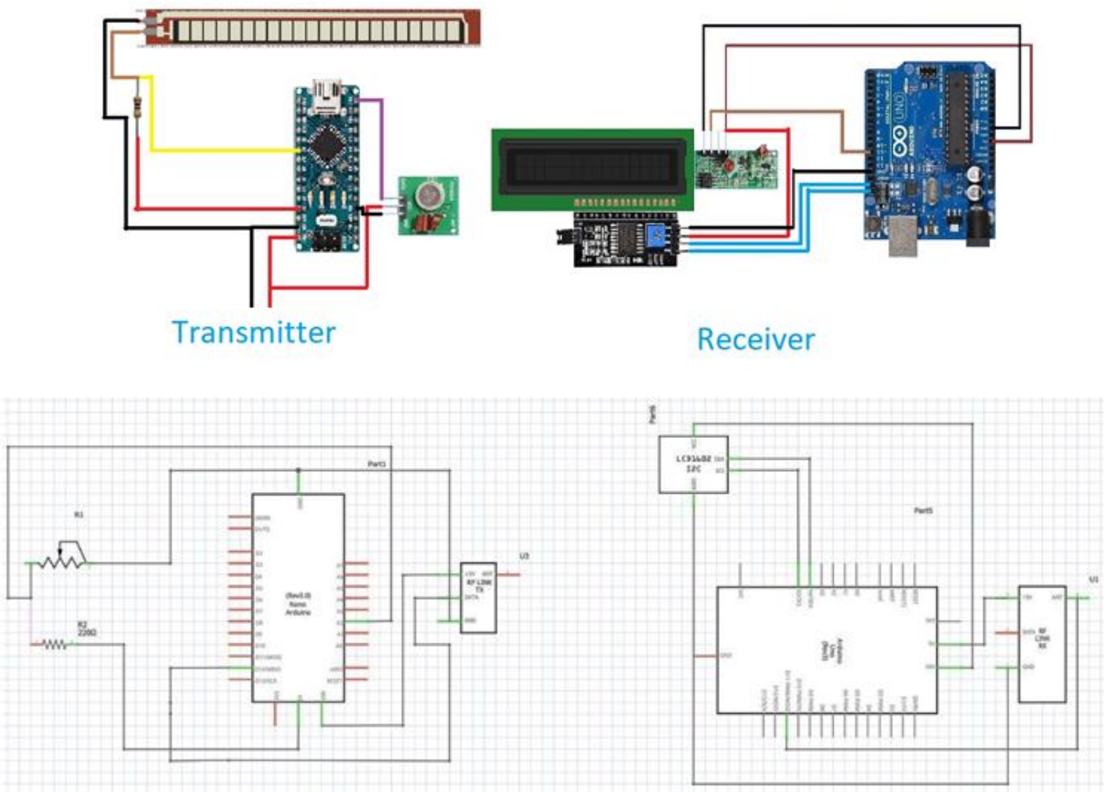

Figure 3: sketch diagram of the two electronic circuits for transmitting and receiving the data on the LCD screen.

Device Calibration:

The calibration of the device was maintained to perform load-displacement curve by applying known weights of 1-25 kg in step of 1 kg. The readings displayed on the LCD screen were monitored and graphed versus the loading values and found to be linearly proportional at the range up to 17 kg, after that nonlinear proportionality was obtained as shown in Figure (4). Therefore, the equation of calibration was taken from the linear part of the curve (Hook's law) and it was considered not to exceed these limits in the loading process during the measurements.

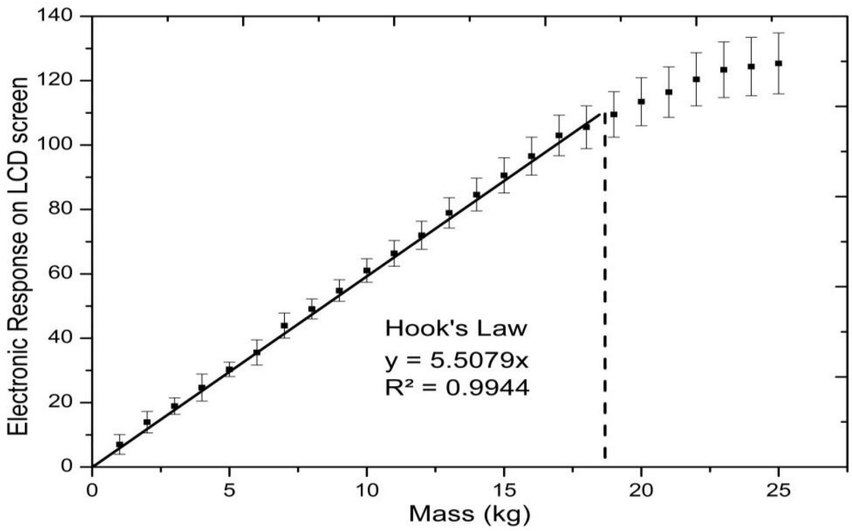

Figure 4: correlation between electronic response readings to the loading of masses and it represents the linear portion that obeying to Hook's law at loading up to 17 kg.

Procedure:

There are no literatures on the most appropriate testing positions for the device use for different groups of muscles. Based on prior research and our own pilot work of assessments in a variety of different positions, we implemented those shown in (figures: 5-8). These testing positions have shown strong reliability for the measurement of contractile force of different muscle groups.

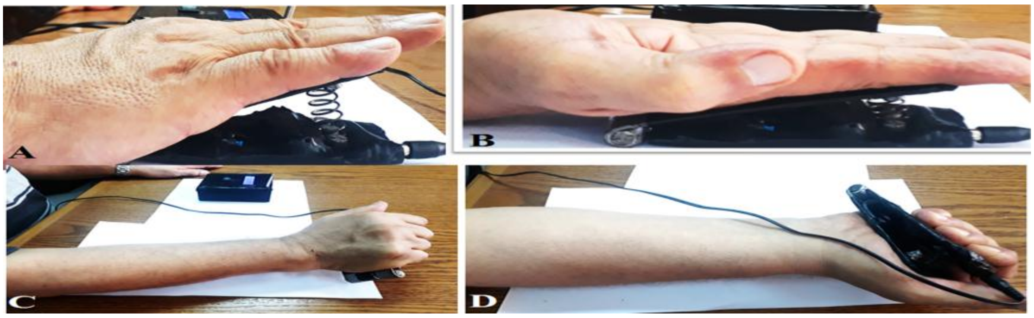

Figure 5: photograph showing different positions for testing different groups of muscles;
A: wrist flexors B: wrist extensors C: pronation D: supination

Figure 6: photograph showing different positions for testing different groups of muscles;
A: **elbow flexors B: shoulder adductors**

Figure 7: photograph showing different positions for testing different groups of muscles;
A: **plantarflexion of foot B: dorsiflexion of foot**

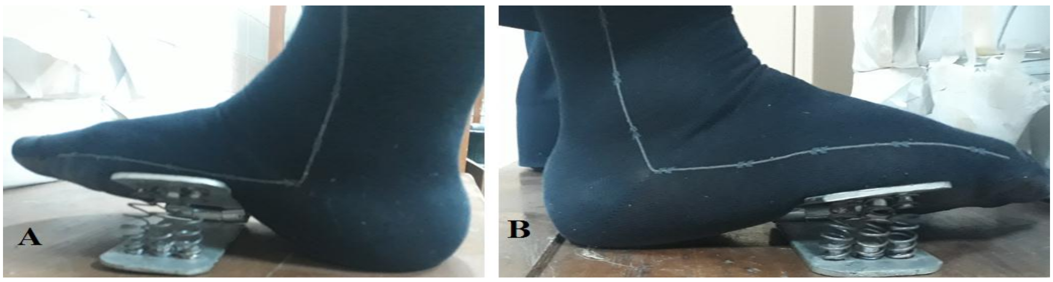

Figure 8: photograph showing different positions for testing different groups of muscles;
A: **eversion of foot B: inversion of foot**

Statistical analysis of the data [6, 8]

Data were fed to the computer using IBM SPSS software package version 20.0. Quantitative data were described using mean and standard deviation for normally distributed data. For normally distributed data, comparison between two independent population were done using independent t-test while more than two population were analyzed F-test (ANOVA) to be used. Significance test results are quoted as two-tailed probabilities. Significance of the obtained results was judged at the 5% level.

Where X and Y are the values of the first and second obs–ervations in the same individual. correlation can be significant $p < 0.05$.

Cohen's kappa coefficient (κ) is a statistic which measures inter-rater agreement for qualitative (categorical) items. It is generally thought to be a more robust measure than simple percent agreement calculation, as κ takes into account the possibility of the agreement occurring by chance. There is controversy surrounding Cohen's kappa due to the difficulty in interpreting indices of agreement. Some researchers have suggested that it is conceptually simpler to evaluate disagreement between items.

Results:

Comparison between first and second measures for different groups of muscles:

Comparison between measurements at first and second times for supination and pronation of upper limb, it was found that there was no significant difference between the 2 readings in both upper limbs, this data was shown in table (3).

On comparing measurements at first and second time for flexion and extension of the hand, it was found that there was no significant difference between the two readings regarding both upper limbs, this data was shown in table (3).

On comparing measurements at first and second time for flexion of the elbow, it was found that there was no significant difference between the two readings regarding both upper limbs, this data was shown in table (3).

On comparing measurements at first and second time for adduction of shoulder, it was found that there was no significant difference between the two readings regarding both upper limbs, this data was shown in table (3).

On comparing measurements at first and second time for eversion and inversion of the foot, it was found that there was no significant difference between the two readings regarding both lower limbs, this data was shown in table (4).

On comparing measurements at first and second time for planterflexion and dorsiflexion of the foot, it was found that there was no significant difference between the two readings regarding both lower limbs, this data was shown in table (4).

Table (5) shows the correlation between the 1st and 2nd measurements, from this table it was found that there was a highly significant positive correlation between the 1st and 2nd measurements, the kappa in all variables was more than 0.70, it indicates a high association and agreement of the two measurements.

Table (3): Comparison between measurements at first and second time in all variables in all groups for upper limb.

Group Mean±SD	Pronation Right Forearm	Pronation Left Forearm	Supination Right forarm	Supination left Forearm	Flexion Right Wrist	Flexion Left Wrist	Extention Right Wrist	Extention Left Wrist	Flexion Right Elbow	Flexion Left Elbow	Right Shoulder	Left Shoulder
Elderly female 1st	2935.64±137.50	28120.69±271.08	28739.31±228.98	28559.71±256.38	28992.08±233.90	28825.78±261.42	29058.60±194.01	28869.02±207.99	28310.26±259.82	28133.99±232.83	27771.47±223.64	27538.65±223.11
Elderly female 2nd	2935.63±137.49	28120.69±271.07	28739.31±228.97	28559.71±256.37	28992.07±233.89	28825.78±261.42	29058.60±194.02	28869.01±207.99	28310.27±259.83	28133.99±232.82	27771.47±223.63	27538.65±223.11
P	0.40	0.33	0.69	0.76	0.48	0.39	0.52	0.29	0.84	0.67	0.86	0.29
Elderly female 1st	2937.33±22.77	2891.52±22.77	28885.65±223.11	28789.20±228.98	29035.32±223.11	28789.20±228.98	29184.98±223.11	29012.03±245.76	28935.54±223.11	28296.96±237.92	28792.52±233.90	28280.33±214.88
Elderly female 2nd	2937.34±22.76	2891.53±22.77	28885.65±223.11	28789.19±228.98	29035.31±223.10	28789.19±228.98	29184.97±223.11	29012.03±245.75	28935.54±223.12	28296.97±237.91	28792.52±233.90	28280.33±214.88
P	0.40	0.33	0.69	0.76	0.48	0.39	0.52	0.29	0.84	0.67	0.86	0.29
Patient female1st	2876.25±22.77	27788.10±223.11	27987.65±223.11	27754.84±249.21	28343.52±233.90	28207.16±244.99	28483.21±255.41	28313.59±224.59	28306.94±244.99	28137.32±223.11	27222.69±265.78	26956.61±290.08
Patient female2nd	2876.25±22.76	27788.10±223.10	27987.65±223.11	27754.84±249.20	28343.53±233.90	28207.17±244.98	28483.21±255.41	28313.60±224.59	28306.94±244.98	28137.33±223.11	27222.69±265.77	26956.61±290.08
P	0.42	0.80	0.30	0.26	0.82	0.32	0.89	0.51	0.45	0.43	0.49	0.76
Patient male1st	2886.43±22.93	28190.53±228.98	28286.98±223.11	28104.06±288.85	28286.98±223.11	28137.32±234.76	28536.43±223.11	28286.98±223.11	28569.69±203.67	28426.67±237.92	27721.58±256.24	27551.96±288.73
Patient male2nd	2886.43±22.93	28190.54±228.98	28286.99±223.10	28104.07±288.85	28286.99±223.10	28137.33±234.76	28536.43±223.11	28286.99±223.10	28569.69±203.66	28426.67±237.93	27721.59±256.24	27551.95±288.74
v	0.49	0.72	0.60	0.64	0.38	0.80	0.36	0.59	0.40	0.41	0.26	0.76
Female Students College1st	2966.18±21.66	28812.48±259.82	29035.32±223.11	28915.58±244.99	28985.43±223.11	28789.20±228.98	29012.03±245.76	28799.18±306.07	29135.09±223.11	28962.15±262.55	28586.32±223.11	28420.02±243.43
Female Students College2nd	2966.19±21.65	28812.48±259.83	29035.31±223.10	28915.58±245.00	28985.43±223.11	28789.19±228.98	29012.03±245.75	28799.17±306.06	29135.09±223.10	28962.15±262.54	28586.32±223.10	28420.02±243.44
P	0.41	0.59	0.79	0.34	0.94	0.26	0.39	0.65	0.78	0.51	0.75	0.40
Male Students College1st	2970.59±20.53	28935.54±223.11	29135.09±223.11	28965.47±249.30	29131.77±228.98	28935.54±223.11	29135.09±307.54	28822.46±241.08	29334.65±223.11	28982.10±282.51	28573.01±241.08	28400.06±222.68
Male Students College2nd	2970.59±20.53	28935.54±223.12	29135.09±223.10	28965.47±249.31	29131.76±228.98	28935.54±223.12	29135.09±307.53	28822.45±241.08	29334.65±223.11	28982.09±282.51	28573.01±241.08	28400.07±222.69
P	0.30	0.88	0.88	0.33	0.77	0.23	0.33	0.46	0.22	0.58	0.25	0.82
School Students Female1st	2911.88±22.76	28366.81±244.99	28489.86±248.35	28330.22±225.38	28286.98±223.11	28153.95±243.43	28373.46±241.08	28240.42±221.89	28127.34±228.77	27961.04±257.07	28882.32±228.98	28742.64±233.90
School Students Female2nd	2911.87±22.77	28366.81±244.99	28489.87±248.35	28330.22±225.38	28286.99±223.10	28153.95±243.43	28373.46±241.08	28240.43±221.88	28127.35±228.79	27961.05±257.07	28882.32±228.99	28742.63±233.89
P	0.30	0.88	0.88	0.33	0.77	0.23	0.33	0.46	0.22	0.58	0.25	0.82
School Students Male1st	2937.33±22.77	28646.18±237.92	28825.78±237.92	28596.29±237.92	28745.96±237.92	28602.95±282.00	28606.27±256.33	28446.63±263.45	28905.61±202.03	28656.16±214.83	28978.78±235.41	28839.09±248.35

Group Mean±SD	Pronation Right Forearm	Pronation Left Forearm	Supination Right forarm	Supination left Forearm	Flexion Right Wrist	Flexion Left Wrist	Extention Right Wrist	Extention Left Wrist	Flexion Right Elbow	Flexion Left Elbow	Right Shoulder	Left Shoulder
School Students Male2nd	2937.34±22.76	28646.19±237.91	28825.78±237.91	28596.29±237.90	28745.96±237.91	28602.95±281.99	28606.27±256.32	28446.63±263.46	28905.61±202.04	28656.16±214.82	28978.77±235.42	28839.09±248.35
P	0.67	0.50	0.42	0.40	0.46	0.58	0.67	0.30	0.89	0.75	0.27	0.64
Female School students 1st	29322.18±140.48	29191.22±181.72	29397.01±105.83	29241.11±117.57	28985.43±155.49	28866.94±145.91	28885.65±221.51	28723.51±232.09	28979.19±181.72	28823.29±157.20	28985.43±209.97	28835.76±221.51
Female School students 2nd	29322.18±140.46	29191.21±181.72	29397.00±105.82	29241.10±117.55	28985.43±155.49	28866.95±145.90	28885.65±221.51	28723.51±232.09	28979.20±181.72	28823.28±157.19	28985.44±209.97	28835.74±221.51
v	0.45	0.48	0.21	0.66	0.86	0.24	0.53	0.21	0.71	0.71	0.27	0.58
Male School students1st	2988.97±12.27	2975.15±14.35	29284.76±107.77	29135.09±107.77	29099.46±134.22	28999.68±134.22	29013.94±179.55	28835.76±107.77	28800.13±307.15	28636.21±296.55	28686.10±263.99	28522.17±342.89
Male School students2nd	2988.97±12.25	2975.16±14.34	29284.76±107.75	29135.10±107.80	29099.44±134.22	28999.67±134.23	29013.91±179.54	28835.76±107.75	28800.11±307.17	28636.21±296.53	28686.09±263.98	28522.19±342.87
P	0.36	0.32	0.43	0.31	0.27	0.57	0.31	0.42	0.65	0.29	0.35	0.62
Swimming Female1st	3008.60±22.77	29584.09±212.50	29444.41±246.72	29574.12±228.78	29334.65±237.02	29484.32±223.11	29311.37±245.76	29480.99±228.98	29281.44±220.28	29510.92±221.40	28958.82±258.45	29474.34±237.92
Swimming Female2nd	3008.61±22.76	29584.09±212.49	29444.40±246.72	29574.11±228.77	29334.64±237.03	29484.31±223.10	29311.36±245.77	29480.99±228.98	29281.43±220.28	29510.92±221.40	28958.81±258.44	29474.33±237.91
P	0.45	0.48	0.21	0.66	0.86	0.24	0.53	0.21	0.71	0.71	0.27	0.58
Swimming Male 1st	3003.17±23.37	3013.02±23.87	29284.76±223.11	29524.23±237.92	29391.19±296.87	29514.25±249.30	29381.21±240.35	29534.21±223.11	29284.76±223.11	29467.69±243.43	29135.09±239.26	29268.13±243.43
Swimming Male 2nd	3003.18±23.36	3013.01±23.86	29284.75±223.11	29524.22±237.91	29391.18±296.87	29514.25±249.29	29381.21±240.36	29534.20±223.10	29284.75±223.11	29467.69±243.43	29135.09±239.26	29268.12±243.44
P	0.52	0.53	0.29	0.49	0.85	0.77	0.80	0.84	0.76	0.84	0.88	0.31
Female fencing1st	3010.64±25.00	29414.47±244.99	29500.95±243.43	29391.19±270.55	29487.64±281.88	29351.28±275.63	29384.54±223.11	29254.83±259.78	29161.70±262.55	29022.01±241.08	29341.30±316.57	29045.29±271.42
Female fencing2nd	3010.64±24.99	29414.47±244.99	29500.94±243.42	29391.19±270.56	29487.63±281.88	29351.27±275.63	29384.54±223.12	29254.82±259.78	29161.69±262.54	29022.01±241.08	29341.29±316.59	29045.29±271.42
P	0.31	0.49	0.60	0.25	0.94	0.21	0.78	0.64	0.89	0.62	0.57	0.63
Male fencing 1st	3010.64±25.00	29354.61±244.98	29500.95±250.63	29351.28±220.44	29534.21±223.11	29354.61±279.56	29301.39±243.43	29151.72±250.63	29155.05±357.67	29065.25±285.22	29181.66±453.12	28965.47±368.44
Male fencing 2nd	3010.64±24.99	29354.61±245.00	29500.94±250.62	29351.28±220.44	29534.20±223.10	29354.60±279.56	29301.39±243.44	29151.71±250.62	29155.05±357.68	29065.24±285.22	29181.65±453.13	28965.47±368.44
P	0.25	0.83	0.40	0.72	0.70	0.45	0.49	0.51	0.53	0.80	0.81	0.47
Female Athletics 1st	3009.62±24.28	29394.52±237.92	29534.21±223.11	29427.78±245.76	29288.09±280.61	29168.35±250.63	29218.24±290.08	29091.86±261.19	29331.32±228.98	29121.79±278.07	29457.71±257.07	29228.22±250.06

Group Mean±SD	Pronation Right Forearm	Pronation Left Forearm	Supination Right forarm	Supination left Forearm	Flexion Right Wrist	Flexion Left Wrist	Extention Right Wrist	Extention Left Wrist	Flexion Right Elbow	Flexion Left Elbow	Right Shoulder	Left Shoulder
Female Athletics 2nd	3009.62±24.26	29394.51±237.92	29534.20±223.10	29427.77±245.76	29288.08±280.63	29168.35±250.63	29218.23±290.08	29091.85±261.18	29331.32±228.99	29121.78±278.07	29457.71±257.07	29228.21±250.06
P	0.25	0.88	0.90	0.41	0.44	0.60	0.78	0.57	0.55	0.81	0.40	0.40
Male Athletics 1st	3010.64±25.00	29384.54±223.11	29480.99±228.98	29288.09±228.98	29464.36±255.64	29264.81±301.58	29361.26±263.90	29238.20±246.91	29361.26±303.97	29194.96±326.71	29281.44±359.98	29128.44±336.71
Male Athletics 2nd	3010.64±24.99	29384.54±223.12	29480.99±228.98	29288.08±228.99	29464.35±255.64	29264.80±301.59	29361.25±263.90	29238.19±246.91	29361.25±303.98	29194.96±326.71	29281.43±359.99	29128.43±336.71
P	0.31	0.49	0.60	0.25	0.94	0.21	0.78	0.64	0.89	0.62	0.57	0.63
Female Gymnastics1st	2886.43±22.77	28519.80±243.43	28267.03±302.17	28403.39±294.94	27708.27±253.54	27891.20±249.78	28007.61±244.98	28286.98±223.11	27788.10±223.11	28037.54±234.76	28835.76±223.11	29035.32±223.11
Female Gymnastics2nd	2887.11±25.29	2910.52±26.63	28273.69±314.09	28413.37±310.90	27708.27±253.53	27891.20±249.78	28010.94±250.78	28290.31±228.98	27788.10±223.10	28037.55±234.77	28835.75±223.11	29035.31±223.10
P	0.46	0.58	0.62	0.22	0.65	0.63	0.67	0.65	0.69	0.69	0.60	0.54
Male Gymnastics1st	2942.42±22.77	29035.32±223.11	28286.98±223.11	28566.36±253.54	28293.64±233.90	28539.75±238.86	28193.86±233.90	28533.10±228.98	28785.87±223.11	28978.78±213.22	28759.26±208.16	28952.17±247.06
Male Gymnastics2nd	2942.77±23.37	29041.97±233.89	28293.64±235.41	28573.01±263.63	28293.64±233.89	28539.76±238.86	28193.87±233.89	28536.43±233.24	28785.87±223.11	28978.78±213.23	28769.24±229.91	28958.82±260.51
P	0.75	0.64	0.60	0.51	0.42	0.22	0.33	0.50	0.79	0.87	0.93	0.66
Female Taekwondo1st	3025.79±13.59	29546.68±140.47	29746.23±105.83	29609.04±122.20	29297.23±145.45	29209.93±122.20	29166.28±150.70	29029.08±144.68	28617.50±140.95	28386.76±164.38	28629.97±151.88	28424.18±186.19
Female Taekwondo2nd	3025.79±13.58	29546.68±140.51	29746.23±105.81	29609.04±122.21	29297.23±145.44	29209.93±122.19	29166.26±150.70	29029.07±144.70	28617.49±140.94	28386.78±164.38	28629.96±151.87	28424.20±186.19
P	0.47	0.91	0.64	0.33	0.74	0.79	0.36	0.83	0.51	0.71	0.28	0.65
Male Taekwondo1st	3031.88±15.23	29569.84±134.22	29691.00±120.25	29576.97±164.02	29477.19±120.25	29377.41±120.25	29413.05±140.69	29242.00±120.25	28835.76±107.77	28707.48±143.60	28899.90±134.22	28686.09±107.77
Male Taekwondo2nd	3031.87±15.22	29569.84±134.25	29691.00±120.23	29576.96±164.03	29477.19±120.25	29377.40±120.23	29413.04±140.68	29242.00±120.23	28835.76±107.75	28707.47±143.62	28899.90±134.21	28686.10±107.80
P	0.46	0.58	0.62	0.22	0.65	0.63	0.67	0.65	0.69	0.69	0.60	0.54

Table (4): Comparison between measurements at first and second time in all variables in all groups for lower limb.

Group Mean±SD	Right Foot planterflexion	Left Foot planterflexion	Right Foot dorsiflexion	Left Foot dorsiflexion	Right Foot Eversion	Left Foot Eversion	Right Foot Inversion	Left Foot Inversion
Elderly female 1st	29035.32±223.11	28862.37±292.04	29022.01±241.08	28779.22±316.57	28692.75±233.90	28559.71±287.13	28785.87±223.11	28599.62±304.32
Elderly female 2nd	29035.31±223.10	28862.37±292.05	29022.01±241.08	28779.22±316.57	28692.75±233.89	28559.71±287.12	28785.87±223.11	28599.62±304.31
P	0.52	0.34	0.83	0.53	0.43	0.59	0.60	0.21
Elderly female 1st	29035.32±223.11	28789.20±221.88	29284.76±223.11	29091.86±233.90	28985.43±223.11	28822.46±272.90	28785.87±223.11	28632.88±228.98
Elderly female 2nd	29035.31±223.10	28789.19±221.89	29284.75±223.11	29091.85±233.89	28985.43±223.11	28822.46±272.90	28785.87±223.11	28632.88±228.97
P	0.52	0.34	0.83	0.53	0.43	0.59	0.60	0.21
Patient female1st	28326.89±237.92	28210.49±244.31	28436.65±223.11	28277.01±211.83	28366.81±202.03	28267.03±217.30	28366.81±202.03	28233.77±224.28
Patient female2nd	28326.90±237.91	28210.49±244.30	28436.65±223.11	28277.01±211.83	28366.81±202.04	28267.03±217.29	28366.81±202.04	28233.77±224.27
P	0.55	0.29	0.56	0.81	0.81	0.87	0.94	0.60
Patient male1st	28479.89±214.88	28366.81±244.99	28376.78±237.92	28253.72±260.37	28536.43±223.11	28420.02±242.70	28286.98±223.11	28137.32±223.11
Patient male2nd	28479.89±214.89	28366.81±244.99	28376.79±237.92	28253.73±260.36	28536.43±223.11	28420.02±242.71	28286.99±223.10	28137.33±223.11
v	0.52	0.29	0.79	0.37	0.64	0.75	0.55	0.73
Female Students College1st	29118.46±203.67	28985.43±223.11	29055.27±196.68	28908.93±250.77	28805.83±252.14	28699.40±241.09	28885.65±223.11	28735.98±223.11
Female Students College2nd	29118.46±203.67	28985.43±223.11	29055.27±196.68	28908.93±250.77	28805.83±252.14	28699.40±241.07	28885.65±223.11	28735.98±223.10
P	0.85	0.41	0.55	0.26	0.93	0.61	0.47	0.78
Male Students College1st	29314.69±202.03	29188.31±228.98	29058.60±201.21	28958.82±208.16	29065.25±202.03	28885.65±223.11	28872.35±241.08	28742.64±233.90
Male Students College2nd	29314.69±202.04	29188.30±228.98	29058.59±201.21	28958.81±208.16	29065.25±202.03	28885.65±223.11	28872.34±241.09	28742.63±233.89
P	0.39	0.55	0.45	0.67	0.24	0.27	0.39	0.69
School Students Female1st	28895.63±277.26	28769.24±305.60	28985.43±223.11	28832.44±224.27	28785.87±223.11	28632.88±228.98	29028.66±233.90	28882.32±228.98
School Students Female2nd	28895.63±277.26	28769.25±305.59	28985.43±223.11	28832.43±224.28	28785.87±223.11	28632.88±228.97	29028.66±233.89	28882.32±228.99
P	0.39	0.55	0.45	0.67	0.24	0.27	0.39	0.69
School Students Male1st	29035.32±223.11	28918.91±243.43	29085.21±223.11	28885.65±223.11	29131.77±228.98	29008.71±245.76	29035.32±223.11	28859.04±259.82
School Students Male2nd	29035.31±223.10	28918.91±243.44	29085.20±223.10	28885.65±223.11	29131.76±228.98	29008.71±245.77	29035.31±223.10	28859.03±259.83
P	0.78	0.36	0.47	0.38	0.57	0.89	0.26	0.70
Female School students 1st	29253.58±288.37	29135.10±345.64	29309.70±122.21	29216.16±133.17	28941.78±319.37	28810.82±360.74	28692.33±177.76	28586.32±172.82
Female School students 2nd	29253.58±288.38	29135.09±345.64	29309.70±122.18	29216.16±133.16	28941.76±319.38	28810.81±360.72	28692.32±177.78	28586.31±172.80
v	0.91	0.75	0.65	0.45	0.50	0.58	0.76	0.85
Male School students1st	29149.35±250.63	29013.94±286.38	29348.90±134.22	29234.87±107.77	29242.00±281.37	29177.86±294.34	28835.76±107.77	28735.98±107.77
Male School students2nd	29149.34±250.65	29013.93±286.39	29348.90±134.21	29234.87±107.76	29242.00±281.37	29177.86±294.32	28835.76±107.75	28735.99±107.77
P	0.67	0.25	0.26	0.38	0.56	0.69	0.57	0.50
Swimming Female1st	29441.08±233.90	29534.21±223.11	29344.63±209.30	29437.75±228.98	28839.09±284.39	29088.53±320.81	28882.32±285.64	29028.66±278.32

Group Mean±SD	Right Foot planterflexion	Left Foot planterflexion	Right Foot dorsiflexion	Left Foot dorsiflexion	Right Foot Eversion	Left Foot Eversion	Right Foot Inversion	Left Foot Inversion
Swimming Female2nd	29441.07±233.89	29534.20±223.10	29344.63±209.30	29437.75±228.98	28839.09±284.40	29088.53±320.81	28882.32±285.64	29028.66±278.32
P	0.91	0.75	0.65	0.45	0.50	0.58	0.76	0.85
Swimming Male 1st	29434.43±223.11	29517.58±257.63	29347.95±206.10	29480.99±223.48	29311.37±201.21	29427.78±233.90	28879.00±242.85	29135.09±223.11
Swimming Male 2nd	29434.43±223.11	29517.57±257.61	29347.95±206.10	29480.99±223.48	29311.36±201.21	29427.77±233.90	28878.99±242.86	29135.09±223.10
P	0.62	0.72	0.46	0.33	0.53	0.21	0.50	0.69
Female fencing1st	29534.21±223.11	29434.43±223.11	29384.54±223.11	29284.76±223.11	29377.89±233.90	29281.44±268.97	29085.21±223.11	28935.54±223.11
Female fencing2nd	29534.20±223.10	29434.43±223.11	29384.54±223.12	29284.75±223.11	29377.89±233.91	29281.43±268.98	29085.20±223.10	28935.54±223.12
P	0.40	0.83	0.33	0.59	0.52	0.42	0.68	0.60
Male fencing 1st	29534.21±223.11	29391.19±216.53	29328.00±233.90	29234.87±223.11	29361.26±201.21	29231.55±228.98	29301.39±203.67	29115.14±244.99
Male fencing 2nd	29534.20±223.10	29391.19±216.54	29327.99±233.91	29234.86±223.12	29361.25±201.21	29231.54±228.98	29301.39±203.67	29115.13±244.98
P	0.44	0.62	0.29	0.88	0.25	0.51	0.87	0.88
Female Athletics 1st	29514.25±244.99	29411.15±256.38	29484.32±223.11	29384.54±223.11	29284.76±223.11	29188.31±228.98	29371.24±244.02	29228.22±233.90
Female Athletics 2nd	29514.25±244.98	29411.14±256.39	29484.31±223.10	29384.54±223.12	29284.75±223.11	29188.30±228.98	29371.23±244.03	29228.21±233.90
P	0.69	0.63	0.47	0.22	0.94	0.84	0.45	0.65
Male Athletics 1st	29524.23±224.06	29434.43±223.11	29484.32±223.11	29364.58±251.43	29484.32±223.11	29334.65±223.11	29377.89±233.90	29268.13±247.78
Male Athletics 2nd	29524.22±224.06	29434.43±223.11	29484.31±223.10	29364.58±251.43	29484.31±223.10	29334.65±223.11	29377.89±233.91	29268.11±247.78
P	0.40	0.83	0.33	0.59	0.52	0.42	0.68	0.60
Female Gymnastics1st	28436.65±223.11	28579.66±233.90	28735.98±223.11	28885.65±223.11	28333.55±217.84	28473.23±255.41	28393.41±224.59	28523.12±233.59
Female Gymnastics2nd	28446.63±240.15	28586.32±244.40	28735.98±223.10	28888.97±228.99	28340.20±228.98	28479.89±266.58	28400.06±238.11	28529.78±247.19
P	0.74	0.53	0.23	0.46	0.52	0.32	0.66	0.59
Male Gymnastics1st	29165.03±160.89	29258.15±201.21	29058.60±201.21	29184.98±270.64	29035.32±223.11	29118.46±243.43	28835.76±223.11	28948.84±238.12
Male Gymnastics2nd	29145.78±147.98	29238.43±193.19	29053.13±216.67	29177.86±286.16	29046.01±243.76	29131.53±262.13	28835.76±242.84	28942.66±253.52
P	0.25	0.47	0.53	0.38	0.86	0.54	0.38	0.38
Female Taekwondo1st	29309.70±122.21	29178.75±151.88	29658.93±122.20	29559.15±122.20	28891.89±171.66	28785.87±184.75	29004.14±133.17	28910.60±122.21
Female Taekwondo2nd	25667.81±10371.84	25555.56±10326.83	25973.39±10495.31	25886.09±10460.03	25243.76±10200.78	25156.45±10165.92	25405.89±10266.01	25318.59±10230.74

Group Mean±SD	Right Foot planterflexion	Left Foot planterflexion	Right Foot dorsiflexion	Left Foot dorsiflexion	Right Foot Eversion	Left Foot Eversion	Right Foot Inversion	Left Foot Inversion
P	0.55	0.79	0.30	0.37	0.63	0.39	0.39	0.88
Male Taekwondo1st	29441.56±120.25	29306.14±149.27	29726.63±120.25	29633.98±107.77	29099.46±134.22	29006.81±149.27	29234.87±107.77	29135.09±107.77
Male Taekwondo2nd	29441.54±120.25	29306.14±149.26	29726.63±120.23	29633.99±107.77	29099.44±134.22	29006.80±149.28	29234.87±107.76	29135.10±107.80
P	0.74	0.53	0.23	0.46	0.52	0.32	0.66	0.59

Table (5): Correlations between 1st and 2nd measurements for different studied variables.

Upper limb	Pearson Correlation	P value	k
Pronation Right forearm	0.358**	0.0001	0.95
Pronation Left forearm	0.455**	0.0001	0.90
Supination Right forearm	-0.274**	0.0001	0.94
Supination left forearm	-0.255**	0.0001	0.92
Flexion Right Wrist	1.000**	0.0001	0.91
Flexion Left Wrist	1.000**	0.0001	0.96
Extension Right Wrist	1.000**	0.0001	0.95
Extension Left Wrist	1.000**	0.0001	0.91
Flexion Right Elbow	1.000**	0.0001	0.89
Flexion Left Elbow	1.000**	0.0001	0.92
Right Shoulder	1.000**	0.0001	0.95
Left Shoulder	1.000**	0.0001	0.96
Lower limb			
Right Foot planterflexion	0.364**	0.0001	0.91
Left Foot planterflexion	0.399**	0.0001	0.91
Right Foot dorsiflexion	0.343**	0.0001	0.92
Left Foot dorsiflexion	0.370**	0.0001	0.96
Right Foot eversion	0.422**	0.0001	0.92
Left Foot eversion	0.438**	0.0001	0.96
Right Foot inversion	0.395**	0.0001	0.90
Left Foot inversion	0.407**	0.0001	0.91

Discussion

Hand-held dynamometry (HHD) has never previously been used to examine isometric muscle power. Rate of force development (RFD) is often used for muscle power assessment [13]. The aim of this study was to examine of a new device for assessment of the force of different groups of muscles of the upper limb. Up to our current knowledge, there is no device that can measure the contractile force of different muscles in a limb. This was the reason for inventing this device and therefore we decided to assess of this device on different groups of muscles of upper limb.

To achieve this purpose, muscles of the upper and lower limb of 270 subjects have been examined; 135 athletic and 135 non-athletic (males and females at different age groups and different BMI). The force muscles in each subject were assessed on two sessions 2 weeks apart.

This device has low-cost, portable, and easy-to-use as a clinically-feasible alternative to laboratory-based dynamometry for the assessment of isometric muscle strength.

Previous literature has focused primarily on the assessment and treatment of muscle strength in various clinical populations; however, muscle power is another important consideration. Evidence indicates that in an elderly population, measures of muscle power are more strongly associated with self-reported function and incidence of falls than muscle strength [4,13]. Handgrip strength appears to be the most widely used method for the measurement of muscle strength, it is widely used because it can be easily measured in the clinical setting [7].

Clinicians, both from the fields of geriatric medicine and rheumatology, prefer the use of grip strength over chest press and lower limb isokinetic dynamometry as a measure of overall muscle strength[2]. Isometric handgrip strength shows a good correlation with leg strength and also with lower extremity power and calf cross-sectional muscle area [12]. A potential limiting factor for HHD is the lack of widely available software to extract the RFD data [13]. For this reason we have created freely available software program which allows the user to perform load-displacement curve by applying known weights of 1-25 kg in step of 1 kg. The readings displayed on the LCD screen were monitored and graphed versus the loading values and found to be linearly proportional at the range up to 17 kg.

In the present work, 3 professional assessors shared in the assessment of each group in 2 sessions 2 weeks apart which make the results more accurate and reliable. The assessors were randomly distributed to the different study places. In our experience, sufficient strength levels are required to control the movement of the patient, after which the technique of the assessor is likely to be just as important for obtaining valid results. Although the new device can be applied to any part of the body, yet we applied it to the muscles of the upper limb. This made the study applicable on children and elderly also to prove that there is device that can be applied for the upper limb, we used only pronators, supinators, hand flexors and extensors, elbow extensors and shoulder adductors.

For the treatment of sarcopenia, muscle mass is used. Nevertheless, these methods require massive, costly and non-portable equipment, thereby restricting their use in routine clinical practice. Computer tomography (CT) scanning and magnetic resonance imaging (MRI) allow for precise bone, fat and lean body tissue differentiation and are gold standards for muscle mass evaluation [5].

It is stated that the accuracy of muscle strength values measured using isokinetic dynamometers is high [7], but this instrument is large and expensive; its wider use in clinical practice is therefore limited.

In one study by Marmon [11], the participants were advised to maintain an upright position in an end-sitting position with the hip and knee joints bent at 90 °. This test is difficult to be performed by old persons.

It was found that there was a highly significant positive correlation between the 1st and 2nd measurements, the kappa in all variables was more than 0.70, it indicates a high association and agreement of the two measurements; the device for the use in different groups of muscles of the upper limb.

Mentiplay et al. [13] reported that the hip musculature showed the strongest for measures of peak force and RFD. Previous research examining peak force has also found similar results for the assessment of hip strength using HHD in a range of populations [2,5]. HHD in a healthy population has shown poor validity measures of plantarflexor strength in comparison with the electromechanical dynamometer as the gold standard [11]. The group of muscles we have chosen are the muscles that perform the main functions of the upper limb; the prehensive power of the hand and the screwing movement of the forearm.

Starosta et al. [17] in their study on upper limb impairment in the early phase of brain stroke is one of the key problems in rehabilitation. They concluded that neither sex nor the side of the ischemic brain injury influence the muscle force, whereas age determines both muscle force and muscle force deficits. Older post-stroke patients demonstrate fewer deficits in muscle strength than younger ones. In comparison with our device it can assess muscle force in all groups, in all ages and in both sexes.

Conclusions:

This device for the assessment of muscle force of muscles in the upper limb in both sexes and in different age group. It is recommended to extend the study to include the muscles of other parts of the body not for measurements only but also for training.

Conflicts of Interests

The authors have declared that no competing interests exist.

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