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# Association between Anthropometric Characteristics and Ergonomics of Factory Workers: an Observational Study

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**Abstract:**

**Purpose:** the study aim to find the correlation between anthropometric characteristics and ergonomics of factory workers at the age of (25-35) years old.

**Methods:** 290 factory workers at garment production line of both genders were selected and 38 anthropometric measures were measured in addition to hand grip power and assessment of ergonomics at work by RULA scale**.**

**Results:** The Correlation between anthropometric measures, hand grip power and RULA scale were as following: Positive weak Correlation as Trunk in RULA with RT Elbow height stand, shoulder height sitting, Negative weak Correlation as U.L. RULA with RT Shoulder height stand, pelvic height stand, shoulder height sitting, arm circumference, forearm circumference, hand length, and standing leg length. Positive moderate Correlation as Right hand grip power with RT shoulder height stand. Negative moderate Correlation as Right and Left hand grip power with RT ankle circumference. Strong positive Correlation as Right hand grip power with Lt Shoulder height stand, standing leg.

**Conclusion:** there was a correlation between anthropometric measures and hand grip power with RULA score.

**Keywords:** factory workers, garment production line, anthropometric, posture abnormalities, work related musculoskeletal disorders, RULA, hand grip dynamometer.

## 1.Introduction:

Anthropometry is the way of measuring the whole body parts. It is important for the development of specific characteristics for every job and is used by several professional institutions to perfectly choose their employees**.** Morphological characteristics have a great importance for orientation and selection in any job related task. Therefore, Anthropometric measures are extremely important to conceptualize a specification related to every task needed at work (8)**.**

Work-Related Musculoskeletal Disorders (WRMDs) are these problems affecting bones, muscles, and other tissues related to the work environment. The most common injuries that occur due to the job are musculoskeletal injuries (16).

Assessment of safety behaviors for manual workers at their work including several aspects such as safety attitude, safety communication and compliance between commitment and safety. Several studies directed to find association between safety and management as workers' behavior and expected WRMDs (7,14). Rapid Upper Limb Assessment (RULA) is a method to evaluate work

positions performed by the upper body in the ergonomics field.

This is a simple rapid tool to evaluate the neck, back, and the upper body posture, as well as the load exerted by the muscle to perform a function balance with the external load on the body (9).

Rapid Upper Limb Assessment (RULA) is an observational ergonomic tool, used to analyze joint deviations angle at the shoulder, elbow, wrist, trunk and neck in different working positions **(12).**

There was a positive relation between hand grip strength with body height, weight, body mass index (BMI), hand length, body surface area, arm and calf circumferences, skin folds, fat free mass, physical activity and hip waist ratio**(5).** Musculoskeletal disorders could be resulted from faulty acquired work patterns that related to weak handgrip (**13).**

Consequently, the aim of the current study was designed to find the relationship between anthropometric measures, hand grip power and RULA that assess ergonomics and dynamic posture of factory workers.

## 2. Materials and Methods:

### 2.1. Study design:

This is observational study, correlation analysis conducted in SEKEM Company, garment production line, Belbes-Sharkeya from December to February 2022. The current study was conducted in accordance with the guidelines and approved by the local Ethics committee of the Faculty of Physical Therapy, Cairo University No:P.T.REC/012/003558.

### 2.2. Participants:

Two hundred and ninety participants of both gender enrolled in the current study Using G-power software program and regarding T test study, alpha level of 0.05, confidence interval 95% and effect size of 0.20 (to detect small effects), the total sample size will be 262 participant. The sample will be increased by 10% to be a total of 290 for more accuracy.

Participants were asked about their basic personal information and work nature information. All participants are factory workers in the same factory dealing with the same ergonomics with their ages ranging from 25 to 35 years old. Participants filled in a written informed consent after their approval for participation in the current work.

### 2.3. Procedures:

#### 2.3.1. Anthropometric measures (6).

The anthropometric outcome measures were delimited to:

- Height (whole height- shoulder height- elbow height- pelvic height- knee height).
- Weight by digital weight scale.
- Length and circumference (arm and forearm).
- Ankle circumference.
- Hand (length, width and circumference).
- Both feet (length and width).
- Both shoulder width from anterior and posterior.

The laser device was used to assess all measures of height by stabilizing LASER at the starting point and directing perpendicular LASER beam toward the ground. Measurement tape was used to measure length and other measures of length between two bone landmark and circumferences almost at the middle of the part measured. All measurement done three times and the mean value recorded. BMI calculated from the equation (BMI = kg/m2)

#### 2.3.3 Hand grip power.

This was assessed by hand grip dynamometer (serial no. model 10602, baseline, USA, 2019) for right and left side **(5).** Measurement was done from sitting position with shoulder adducted, flexed elbow 90 degrees and forearm and wrist in mid position and supported on a table. The examiner placed the dynamometer in the worker`s hand while gently supporting the base of the dynamometer, and the examiner instructed the worker to hardly squeeze his hand as much as possible. The value of hand grip power was normalized with BMI before correlation between hand grip power and other values of anthropometric and RULA **(11)**.

#### 2.3.4 Ergonomics and dynamic Postural analysis by RULA scale (10, 2).

RULA scale is a tool to evaluate movement associated with tasks. RULA includes 3 tables, the first is score of analysis for upper limb load during work regarding ergonomics, the second is score of analysis for trunk and the third is the resultant score of UL and Trunk and is called Total RULA. The outcome measures of total RULA was be scored from 1 to 7

Level 1: Score of 1-2 = Acceptable
Level 2: Score of 3-4 = Investigate further
Level 3: Score of 5-6 = Investigate further and change soon
Level 4: Score of 7 = Investigate further and change immediately.

Increase in UL RULA score only or increase in Trunk RULA only could give high total RULA score, so correlations done between anthropometric measures and hand grip power with the 3 scores of RULA (UL, Trunk and Total).

## 3. Data analysis:

The statistical analysis was conducted by using statistical SPSS Package program version 25 for Windows (SPSS, Inc., Chicago, IL). Data are expressed as mean and standard deviation for demographic data (age, years, height, weight, BMI, and foot size), anthropometric measures, RULA scale, and hand grip power.

Data of gender and dominant hand are expressed as frequency and percentage. shapero wilk test revealed that data were not normally distributed. Pearson correlation coefficient was performed to compute the relation between right and left anthropometric measures with RULA scale, and hand grip power. All statistical analyses were significant at probability ($p \leq 0.05$).

## 4. Results:

A total of 290 workers participated in the current study to evaluate correlation between anthropometric measures, hand grip power and RULA scale.

The mean values of age, years of experience, height; weight, BMI, and foot size were presented in **table (1).** The gender distribution for males and females was 222 (76.60%): 68 (23.40%), respectively, and right and left dominant hand was 273 (94.10%): 17 (5.90%), respectively The mean values of RULA scale (U.L., Trunk, and total) were 4.53 ±1.06, 5.11 ±1.56, and 5.36 ±1.31, respectively, right and left hand grip power were 1.28 ±0.53 and 1.20 ±0.54, respectively as shown in **table (2).** The mean values of anthropometric measures for both sides (right and left) are presented in **table (3).**

**Table1. General demographic data characteristics of the study population**

| Variables | Demographic data values Mean ± SD (n=290) |
|---|---|
| **Age (year)** | 30.61 ±4.25 |
| **Working years** | 7.38 ±4.22 |
| **Height (cm)** | 167.18 ±9.15 |
| **Weight (Kg)** | 78.44 ±14.59 |
| **BMI (kg/m$^2$)** | 28.17 ±5.41 |
| **Foot size (cm)** | 41.81 ±2.19 |
| **Gender (Males : Females)** | 222 (76.60%): 68 (23.40%) |

**Table 2. Mean values of RULA scale and hand grip power in the study population**

| Variables | | Items Mean ±SD (n=290) |
|---|---|---|
| **RULA scale** | **U.L.** | 4.53 ±1.06 |
| | **Trunk** | 5.11 ±1.56 |
| | **Total** | 5.36 ±1.31 |
| **Hand grip power** | **Right** | 1.28 ±0.53 |
| | **Left** | 1.20 ±0.54 |

Quantitative data (age, years, height, weight, Body Mass Index (BMI), and foot size) are expressed as mean ±standard deviation. Qualitative data (gender and dominant hand) are expressed as number and percentage Data are expressed as mean ±standard deviation.

**Table 3. Mean values of Anthropometric measures in the study population group**

| Anthropometric measures | side | Mean ±SD (n=290) |
|---|---|---|
| **Shoulder height stand** | Right | 139.48 ±7.71 |
| | Left | 139.67 ±6.92 |
| **Elbow height stand** | Right | 105.35 ±5.71 |
| | Left | 104.89 ±5.66 |
| **Pelvic height stand** | Right | 98.98 ±5.52 |
| | Left | 99.50 ±5.60 |
| **Knee height stand** | Right | 46.98 ±3.33 |
| | Left | 46.68 ±3.33 |
| **Shoulder height sitting** | Right | 58.24 ±4.99 |
| | Left | 58.42 ±5.02 |
| **Shoulder width** | Interior | 45.23 ±3.64 |
| | Posterior | 50.78 ±5.34 |
| **Arm length** | Right | 35.49 ±2.63 |
| | Left | 35.20 ±2.42 |
| **Arm circumference** | Right | 32.66 ±3.35 |
| | Left | 32.42 ±3.71 |
| **Forearm length** | Right | 29.08 ±2.07 |
| | Left | 28.62 ±2.33 |
| **Forearm circumference** | Right | 28.20 ±2.40 |
| | Left | 28.13 ±2.45 |
| **Hand length** | Right | 20.05 ±1.51 |
| | Left | 20.04 ±1.40 |
| **Hand width** | Right | 10.25 ±0.91 |
| | Left | 10.18 ±0.91 |
| **Hand circumference** | Right | 20.75 ±1.53 |
| | Left | 20.47 ±1.50 |
| **Standing leg length** | Right | 45.25 ±3.91 |
| | Left | 45.05 ±3.90 |
| **Ankle circumference** | Right | 24.46 ±3.01 |
| | Left | 24.34 ±2.43 |
| **Foot length** | Right | 25.09 ±1.93 |
| | Left | 25.01 ±1.89 |
| **foot width** | Right | 11.26 ±0.94 |
| | Left | 11.28 ±1.13 |

**Data are expressed as mean ±standard deviation**

Pearson correlation coefficients were computed between right anthropometric measures

and RULA scale (**Table 4**). The results of these correlational analyses revealed that there were significantly ($p<0.05$) negative weak relation between U.L. with shoulder height stand (r=-0.12; P=0.033), pelvic height stand (r=-0.18; p=0.002), shoulder height sitting (r=-0.18; p=0.001), arm circumference (r=-0.16; p=0.005), forearm circumference (r=-0.13; p=0.019), hand length (r=-0.15; p=0.007), and standing leg length (r=-0.14; p=0.012), while, no significant correlations ($p>0.05$) between UL and other rest measures of anthropometric.

Moreover, trunk recorded positive significant weak relations with elbow height stand (r=0.14; *p*=0.017), shoulder height sitting (r=0.14; *p*=0.012), and posterior shoulder width (r=0.17; *p*=0.003). There was positive significant weak relations between total RULA scale with elbow height stand (r=0.11; *p*=0.049), posterior shoulder width (r=0.13; P=0.027), hand circumference (r=0.16; *p*=0.005), and feet length (r=0.13; *p*=0.023). Bi-variate Pearson correlation coefficients was computed between right anthropometric measures and right hand grip power (**table 4).**

The results of these correlational analyses revealed that there was positive significant moderate relation between right hand grip power with shoulder height stand (r=0.44; *p*=0.0001), elbow height stand (r=0.48; *p*=0.0001), pelvic height stand (r=0.44; *p*=0.0001), knee height stand (r=0.30; *p*=0.0001), interior shoulder width (r=0.34; *p*=0.0001), posterior shoulder width (r=0.17; *p*=0.001), arm length (r=0.36; *p*=0.0001), forearm length (r=0.30; *p*=0.0001), hand length (r=0.46; *p*=0.0001), hand width (r=0.14; *p*=0.013), hand circumference (r=0.35; *p*=0.0001), standing leg length (r=0.48; *p*=0.0001), and feet length (r=0.39; *p*=0.0001), however, there was negatively significant weak relations between right hand grip power with arm circumference (r=-0.27; *p*=0.0001) and negatively ($p<0.05$) significant moderate relations between right hand grip power and ankle circumference (r=-0.32; *p*=0.0001). On the other hand, there was no relation ($p>0.05$) between other rest measures of anthropometric with right hand grip power. Bi-variate Pearson correlation coefficients were computed between right anthropometric measures and left hand grip power **(table 4**).

The results of these correlational analyses revealed that there was positive significant moderate relation between left hand grip power and shoulder height stand (r=0.43; *p*=0.0001), elbow height stand (r=0.48; *p*=0.0001), pelvic height stand (r=0.45; *p*=0.0001), interior shoulder width (r=0.31; *p*=0.0001), arm length (r=0.34; *p*=0.0001), hand length (r=0.43; *p*=0.0001), hand circumference (r=0.37; *p*=0.0001), standing leg length (r=0.44; *p*=0.0001), and feet length (r=0.36; *p*=0.0001).

Furthermore, there was a positive significant weak relation between left hand grip power with posterior shoulder width (r=0.18; *p*=0.002), knee height stand (r=0.29; p=0.0001), forearm length (r=0.29; *p*=0.0001), hand width (r=0.16; *p*=0.004). However, there were Significant negatively ($p<0.05$) relations between left hand grip power with arm circumference weak relation (r=-0.25; *p*=0.0001) and moderate negative relation with ankle circumference (r=-0.31; *p*=0.0001), while no relations ($p>0.05$) between other rest measures of anthropometric with left hand grip power.

## Discussion:

The purpose of the current study was to find the relationship between anthropometric measures, hand grip power and RULA that assess ergonomics and dynamic posture of factory workers. Eventually, after presentation of the results and according to reports of the previous investigators in fields related to this study, it could be claimed that there was possible correlation between anthropometric measures and hand grip power with RULA scale according to the following major results:

Positive weak Correlation Trunk score in RULA with RT Elbow standing height may be due to short arm length, spinal deviation as scoliosis secondary to trunk muscle imbalance or improper posture maintained for a long period of time.

Positive weak Correlation Trunk score in RULA with Sitting Shoulder height that may be secondary to muscle shortening or spinal deviations which also impose overload on trunk and may cause musculoskeletal symptoms later in life. Positive weak Correlation Trunk score in RULA with Posterior shoulder width which may indicate rounded shoulder and that could hinder fine movement required especially for that line responsible for production of children clothes due to their little measures and therefore greater effort to attach these pieces together and sewing them.

Positive weak Correlation Total RULA score with RT elbow standing height and posterior shoulder width because these were positively correlated with trunk score in RULA.

Positive weak Correlation Total RULA score with Hand circumference which may be correlated with pattern of wrist motion needed during sewing process especially for small clothes which may further facilitate greater range of motion and faster motion.

Positive weak Correlation Total RULA score with Feet length which may be related somehow to the easiness of plantar and dorsi flexion motion needed to push the controller of sewing machine to operate it and start the process of sewing.

**Table 4. Correlation between anthropometric measures**

| Anthropometric measures (Right) | Item | RULA scale | | | hand grip power | |
|---|---|---|---|---|---|---|
| | | U.L | Trunk | Total | Right | Left |
| Shoulder height stand | r | -0.12 | 0.07 | 0.03 | 0.44 | 0.43 |
| | *p*-value | 0.033* | 0.200 | 0.579 | 0.0001* | 0.0001* |
| Elbow height stand | r | -0.08 | 0.14 | 0.11 | 0.48 | 0.48 |
| | *p*-value | 0.150 | 0.017* | 0.049* | 0.0001* | 0.0001* |
| Pelvic height stand | r | -0.18 | 0.03 | -0.03 | 0.44 | 0.45 |
| | *p*-value | 0.002* | 0.597 | 0.609 | 0.0001* | 0.0001* |
| Knee height stand | r | 0.01 | -0.04 | 0.01 | 0.30 | 0.29 |
| | *p*-value | 0.861 | 0.488 | 0.784 | 0.0001* | 0.0001* |
| Shoulder height sitting | r | -0.18 | 0.14 | 0.03 | -0.013 | 0.01 |
| | *p*-value | 0.001* | 0.012* | 0.551 | 0.826 | 0.845 |
| Shoulder width (Interior) | r | -0.06 | 0.10 | 0.08 | 0.34 | 0.31 |
| | *p*-value | 0.279 | 0.068 | 0.150 | 0.0001* | 0.0001* |
| Shoulder width (Posterior) | r | -0.02 | 0.17 | 0.13* | 0.19 | 0.18 |
| | *p*-value | 0.670 | 0.003* | 0.027 | 0.001* | 0.002* |
| Arm length | r | -0.06 | 0.01 | -0.01 | 0.36 | 0.34 |
| | *p*-value | 0.261 | 0.790 | 0.855 | 0.0001* | 0.0001* |
| Arm circumference | r | -0.16 | 0.10 | -0.01 | -0.27 | -0.25 |
| | *p*-value | 0.005* | 0.090 | 0.885 | 0.0001* | 0.0001* |
| Forearm length | r | -0.09 | 0.04 | -0.01 | 0.30 | 0.29 |
| | *p*-value | 0.101 | 0.455 | 0.834 | 0.0001* | 0.0001* |
| Forearm circumference | r | -0.13 | 0.08 | -0.002 | 0.07 | 0.08 |
| | *p*-value | 0.019* | 0.168 | 0.979 | 0.257 | 0.159 |
| Hand length | r | -0.15 | 0.08 | 0.01 | 0.46 | 0.43 |
| | *p*-value | 0.007* | 0.129 | 0.768 | 0.0001* | 0.0001* |
| Hand width | r | 0.04 | 0.04 | 0.070 | 0.14 | 0.16 |
| | *p*-value | 0.435 | 0.435 | 0.237 | 0.013* | 0.004* |
| Hand circumference | r | 0.09 | 0.09 | 0.16 | 0.35 | 0.37 |
| | *p*-value | 0.112 | 0.097 | 0.005* | 0.0001* | 0.0001* |
| Standing leg length | r | -0.14 | -0.03 | -0.05 | 0.48 | 0.44 |
| | *p*-value | 0.012* | 0.590 | 0.369 | 0.0001* | 0.0001* |
| Ankle circumference | r | -0.10 | 0.04 | -0.04 | -0.32 | -0.31 |
| | *p*-value | 0.090 | 0.417 | 0.430 | 0.0001* | 0.0001* |
| Feet length | r | 0.04 | 0.10 | 0.13 | 0.39 | 0.36 |
| | *p*-value | 0.415 | 0.078 | 0.023* | 0.0001* | 0.0001* |
| Feet width | r | -0.09 | 0.07 | 0.01 | 0.07 | 0.10 |
| | *p*-value | 0.094 | 0.201 | 0.825 | 0.179 | 0.077 |

**r: Pearson correlation coefficient values P-value: probability value (Right) with RULA scale and hand grip power , *Significant: (P<0.05)**

Positive weak Correlation Right and Left hand grip power with RT knee standing height which is an indicator of stature height as (1) said, so, increasing stature height results in increase hand grip power. This height is important during the process of selection of the chair height used by such employer during the process of sewing which is important to avoid several musculoskeletal symptoms such as leg pain and numbness due to compression over popliteal fossa and posterior thigh secondary to prolonged sitting over a higher chair.

Positive weak Correlation Right and Left hand grip power with Forearm length and hand width may be due to length tension relationship. This may need to be considered to be applied during selection of manual worker in jobs that need greater hand force on daily basis.

Positive weak Correlation Right and Left hand grip power with Arm circumference which is an indicator of muscle contour and power which needed to be considered for working tasks that need higher power or load.

Negative weak Correlation U.L. RULA score with RT standing shoulder height, pelvic standing height, shoulder sitting height and hand length as increase value of these variables leads to higher UL ROM which facilitate several working activities; moreover, enhance reaching ability of the worker.

Negative weak Correlation U.L. RULA score with Arm circumference and forearm circumference which are indicators of muscle contour and power which may be needed in several higher working demands.

Negative weak Correlation U.L. RULA score with standing leg length, which is indicator of stature height, so increasing stature height results in enhancing UL ROM and this is compatible with (1).

Positive moderate Correlation Right and left hand grip power with RT shoulder standing height, elbow standing height, pelvic standing height, knee standing height, anterior shoulder width, posterior shoulder width, arm length, forearm length, hand length, hand width, hand circumference, standing leg length, and feet length as explained before in positive weak correlation and as mentioned in (5) hand grip strength has a positive relationship with body height, body weight, body mass index, hand length, body surface area, arm and calf circumferences, skin folds, fat free mass, physical activity, hip waist ratio.

Negative moderate Correlation Right and left hand grip power with RT ankle circumference as ankle circumference is an indicator of BMI and this is supported by previous work reported by (3, 15). So, obesity could affect hand grip power negatively.

Strong positive Correlation Right hand grip power with Lt Shoulder standing height. Standing

leg length and also Strong positive Correlation Left hand grip power with Lt Shoulder standing height which need to be considered during designing the dimensions of the chair suitable for this line of clothes production.

The current finding suggested that lower shoulder Level assumed at the dominant side in dominant hand (which is mainly RT hand in the current study) is related to high hand grip power in both hands but greater at the RT side. Moreover, increased value of standing leg length which is indicator of whole height related to increased hand grip power as a result of increased length tension relationship.

The mean values of RULA scale (U.L., Trunk, and total) were 4.53 ±1.06, 5.11 ±1.56, and 5.36 ±1.31 which mean that most of workers are at risk of WRMD. This is due to the observation that all ergonomics can't be adjustable regarding workers' body dimensions which was reported by (4).

Work tasks may not be properly matched with the individual physical characteristics which may be reflected in deterioration in their performance and reduction in their productivity and hence total profit affection. There is a relationship between handgrip strength, work patterns, and acquired musculoskeletal disorders of the upper extremity.

This current study is limited to factory workers and their working nature is repeated movement from sitting position.

Recommendations regarding further researches include collecting and arranging WRMDs and correlate it with RULA or anthropometric measures.

## 6. Conclusion:

There were significant correlations founded between anthropometric measures, RULA and hand grip power consequently When dealing with the same dimensions of workstation for all workers it is very important to select workers regarding to their anthropometric measures because unfitting between body dimensions and workstation results in high RULA which in turn cause WRMD and affect production ability.

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**Conflict of Interests**

Authors declare no potential conflicts of interest.

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