The Effects of Maximum Aerobic Capacity and Ratings of Perceived Exertion on Muscular Strength and Endurance

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ABSTRACT

Grip and pinch strength are the most important factors affecting the hand's performance. This study aimed to evaluate the relationship among maximum aerobic capacity (Vo_{2max}) and ratings of perceived exertion (RPE) with grip and pinch strength and endurance and their impact on these factors. This cross-sectional study was performed among 83 male students and office workers by means of simple random sampling. To assess the Vo_{2max}, RPE, grip and pinch strength and endurance the Step Test, Borg scale, dynamometer and pinch gauge were used, respectively. The findings of the study indicate that there is a direct relationship between the Vo_{2max} with grip strength and endurance, pinch strength and endurance and BMI. On the other hand, there is an indirect relationship between RPE with grip and pinch strength and Vo_{2max}. Moreover, there was no relationship between RPE with grip and pinch endurance. It was also found that there is a direct relationship between the BMI with grip and pinch strength, pinch endurance, and Vo_{2max}. Finally, no relationship was observed between BMI and grip endurance. Moreover, the Vo_{2max} was found to have no influence on the grip and pinch strength and pinch endurance, but it has an influence on the grip endurance. In jobs that require high grip and pinch strength and endurance employed those with high Vo_{2max} so that work-related musculoskeletal disorders (WMSDs) would be prevented.

Keywords: Grip; Pinch Strength; Step Test

INTRODUCTION

In all European countries and most industrialized nation, the most common work-related musculoskeletal disorders (WMSDs) is related to that of the upper limb[1]. When people act level beyond their physiological limit, they encounter fatigue [2]. maximum aerobic capacity (VO_{2max}), as one of the main health-related components, can be assessed via measuring the VO_{2max} [3]. The more one's VO_{2max} is the more his capacity of performing a physical task would be. In other words, he would be able to do the heavy task much more easily[4]. Besides, physiological procedures, using mental analysis in assessing the difficulty level of a task [5]. In industry, it can be considered as an easier procedure for assessing the difficulty level of a task and VO_{2max} [6]. Therefore, the rating of perceived exertion scale (RPE) has an acceptable error of measurement, the main scale introduced by Borg, is the 15-point scale which measures the amount of effort in a range of 6 to 20 [7]. Validity and reliability of the Borg scale have been studied by Skinner *et al.* and by Stamford[8]. Strong grip can potentially result in carpal tunnel syndrome [1]. When the type of grip and its amount of force are not proportional, upper limb motions would be affected, and it would consequently result in fatigue and muscular tension. Although hand grip strength threshold is the best way to identify people at risk of limitation of motion, it is not yet fully known[9]. Grip and pinch strength assess the function of the hand. Grip strength is considered as a sign of general health [10]. Measurement of grip strength provides valuable information about the function and status of the upper limb and the neuromuscular system. Grip strength can also be used as a measure of the amount of muscular damage or neurological impaired caused by trauma or surgery. In addition, grip strength is a good indication of a person's overall physical condition. Assessment of grip strength, compared to other tests, is simple, easy and of high reproducibility [11]. When measured through standard methods and calibrate equipments, hand grip strength measurements would be quite reliable, even if various analysts and different dynamometers are used. Some research papers suggest that grip strength screening is a tool for women at risk for osteoporosis. Studies show that poor grip strength in men, can be used as a predictor of death caused by heart disease and cancer, even when their muscle

density and BMI is normal [12]. In grip strength, the wrist is fixed and the device is kept by all of the fingers [13]. Pinch strength occurs when gripping with any of the fingers or a combination thereof, in concordance with the movement of the thumb whit no palm contact [14]. In Palmar pinch, the palm of the first joint of the thumb is placed on the pinch gauge against the index and middle fingers [15]. In this study, given the importance of the proportionality of grip and pinch strength a,nd endurance with the Vo_{2max} and RPE, we decided to focus on the relationship of grip strength, grip endurance, pinch strength, pinch endurance, BMI, Vo_{2max}, RPE and age. Moreover the impact of Vo_{2max} on the mentioned factors and the differences of parameters recorded for men and women were studied. It was hypothesized that, there was a relationship between Vo_{2max} and RPE with grip strength, grip endurance, pinch strength, pinch endurance. Finally, if the abovementioned parameters are related, we can use the results to choose the best possible job for each individual worker. This would reduce the related job diseases and increase productivity.

MATERIALS AND METHODS

Participants

In this study, cross-sectional, according to the below equation, 83 male students and office workers from Isfahan University of medical science were selected by simple random sampling. Experiments were performed in the ergonomic laboratory. Participants with a history of arm and hand or wrist surgery in the last 3 months or felt pain or had arthritis in their hands and wrists, were excluded from the test[16].

$$\boldsymbol{n = \frac{(z_1 + z_2)^2(1 - r^2)}{r^2} + 2}$$

Z_1: 1.96, Z_2: 84%

r: the correlation coefficient between different variables= 0.3

Procedures

The study was carried out to determine the VO_{2max} by step test according to the method of McArdle, or Queen's College, which is a standard test to determine VO_{2max} .To perform this test, one must start going up and down a step with a height of 41.3 cm. Here, the rhythm of going up and down should be steady. Totally, during the 3 minutes of the test, men are expected to have gone up and down 72 and women 66 times. To measure VO_{2max} in ml per minute, as for one kilogram of body weight, 5 seconds after step test participant's heart rate is accounted for 15 seconds from the radial artery pulse t, then the number is multiplied by four and after inserting the number in the relevant formula, VO_{2max} is reported[17].

Men: VO_{2max} (ml/kg/min)=111.33-0.42 heart rate (bpm)

BMI, heart rate, and VO_{2max} were recorded in some forms. RPE step test is rated by a Borg scale [18]. The scale goes from 6 to 20[19].

In this study, in order to measure grip strength on the basis of American Society of Hand Therapists (ASHT), Participants were asked to sit on the chair while their arms attached to their body and their wrist was placed in a 0-30 extension degree and Ulnar deviation was 0-15 degrees. Then we asked them to use their dominant hand to apply hand grip for three times. The average of their three times application of maximum force to the handle of the dynamometer was recorded in kilogram-force (kg f) as hand their grip strength[20]. The test was administered at 8-10 A.M. and the time break among the three grips was 60 seconds. Moreover, the participants were asked to apply their hand grips for at least three seconds[21]. The analyzer should stand in such a way that the machine is situated in front of his eyes and finally read the rounded number and record it. At the beginning of the test, the following adjustments were made:[16]

1. Adjusting the dynamometer to zero.
2. Checking the suitability of the dynamometer so that its handle is placed on the middle joint of the "ring finger and index finger".
3. Asking participants to sit straight on the chair while their arm attached to their body, and hold the dynamometer (SH 5001 SAEHAN Hydraulic Hand Dynamometer, South Korea) with their dominant hand and. The angle of their elbow should be 90 degrees. The other hand (non- dominant) is placed on their lap [22].

Participant's grip endurance was specified through determining the maximum time (in seconds) that he could continue applying one-third of the maximum voluntary contraction (MVC) [21].

In addition, the participants were instructed to continue their grip as long as they can. The endurance test would stop if any of the following two conditions occurred:

1. When the participants had no strength and energy to continue.
2. The force exerted by him/her is reduced, at least for five seconds, up to ten percent lower than the force exerted at the initial level [22]. Then, the Palmar pinch test was administered twice for the dominant hand by Pinch Gauge and the maximum force was recorded as a result. The reliability and validity of dynamometer are proved for measuring grip strength and are described as standard for measuring grip power. In this study, pinch gauge (SH 5005 SAEHAN Hydraulic Pinch Gauge, South Korea**)** was used to measure pinch strength. Studies show that pinch gauge has high

calibration accuracy and precision [23]. In the present study, grip strength, grip endurance, pinch strength, pinch endurance and RPE were measured before the step test, the measurements of those parameters repeated after doing step test and recording the participant's heart rate.

Statistical analysis

Data analysis was carried out by using SPSS version 20, Pearson correlation coefficient, Wilcoxon test and paired samples t-test. It is noteworthy to mention that $p < 0.05$ was considered significant.

RESULTS

The mean and standard deviation of demographic information of the participants are shown in Table 1.

Table 1: The demographic information of the participants

Variable	Minimum	Maximum	Mean ±SD
age (Year)	19	62	30.15±10.29
Height(cm)	145	182	167.73±6.57
Weight(kg)	44	97	64.40±10.06
BMI(Kg/m2)	16.85	29.94	22.82±2.76

Pearson correlation coefficient showed that there is a direct relationship between V_{o2max} with grip strength, grip endurance, pinch strength, pinch endurance and BMI ($p < 0.05$) and it has the highest correlation with grip strength ($r = 0.871$) and the lowest correlation with the pinch endurance ($r = 0.213$). There was a direct relationship between BMI with grip strength, pinch strength and endurance and Vo_{2max}. However, there was no relationship between BMI and grip strength ($p_{\text{-value}} > 0.05$). While BMI has the highest correlation coefficient ($r = 0.305$) with pinch endurance, it has the lowest correlation coefficient ($r = 0.026$) with grip endurance. Moreover, there was a direct relationship between participant's age and his grip strength and endurance, pinch strength and endurance and Vo_{2max} ($p_{\text{-value}} < 0.05$). The Spearman correlation coefficient showed that there was an inverse relationship between the RPE with grip strength, pinch strength and Vo_{2max}, while there was no relationship between RPE with grip and pinch endurance ($p_{\text{-value}} > 0.05$). The RPE had the highest correlation with grip and pinch strength ($r = -0.028$) and the lowest correlation with the grip endurance ($r = -0.052$). In addition, Pearson correlation coefficient showed that the participant's height had a direct relationship with grip and pinch strength and Vo_{2max} and it showed the highest correlation coefficient ($r = 0.546$) with grip strength. However, there was no relationship between the endurance of grip and pinch. The related data are available in Table 2. The mean, standard deviation, minimum and maximum of grip strength and endurance, pinch strength and endurance Vo_{2max} of the participants are mentioned in Table 3. Wilcoxon test showed that the RPE after the step test was significantly higher than that before the test ($p_{value} \leq 0.001$). Results are mentioned in Table 4. The paired t-test showed that the average grip strength, grip endurance, pinch strength, pinch endurance did not differ before and after the step test. In other words, the participant's Vo_{2max} had an effect on grip endurance ($p_{value} = 0.04$) but it did not affect other parameters listed above. The results are mentioned in Table 5.

Table 2: The relationship among factors including grip strength and endurance, pinch strength and endurance, BMI, Vo_{2max}, RPE and age and height

Variable	Vo2max		RPE		BMI		age		height	
	r	P value	r	P value	r	P value	r	P value	r	P value
grip strength	0.871	≤ 0.001	-0.275	0.012	0.260	0.018	0.649	≤ 0.001	0.546	≤ 0.001
grip endurance	0.399	≤ 0.001	-0.052	0.64	0.026	0.816	0.418	≤ 0.001	0.096	0.386
pinch strength	0.543	≤ 0.001	-0.280	0.010	0.287	0.009	0.376	≤ 0.001	0.398	≤ 0.001
pinch endurance	0.213	0.027	-0.081	0.468	0.305	0.005	0.287	0.009	≤ 0.001	0.998
BMI	0.309	0.004	-0.311	0.004	-	-	-	-	-	-
Vo_{2max}	-	-	-0.251	0.022	0.309	0.004	0.811	≤ 0.001	0.535	≤ 0.001

Table 3: The mean and standard deviation of grip strength and endurance, pinch strength and endurance and Vo_{2max} in participants

Variable	Minimum	Maximum	Mean ±SD
grip strength	13	55	29.94±10.68
grip endurance	5	91	34.32±21.34
pinch strength	4	12	7.49±1.96
pinch endurance	3	120	33.50±22.31
Vo2max	57.13	101.25	78.75±1.51
RPE	6	13	10.42±1. 51

Table 4: Distribution of ratings of perceived exertion before and after the step test

Degree RPE	Description of degree	Before the step test	After the step test	
		Frequency (Percent) N (%)	Frequency (Percent) N (%)	P_{value}
6	Do not apply any pressure	3(3.6)	0	≤0.001
7-8	Ultra-light	6(7.2)	0	
9-10	Very light	16(19.3)	1(1.2)	
11	light	48(57.8)	5(6)	
12-13	A little hard	10(12)	35(42.2)	
14-15	hard	0	26(31.3)	
16-17	very difficult	0	12(14.4)	
18-19	Super hard	0()	3(3.6)	
20	Maximum pressure	0()	1(1.2)	

Table 5: The mean grip strength and endurance, pinch strength and endurance before and after step test performed by the participants

Variable	Before step test	After step test	P_{value}
	Mean ±SD	Mean ±SD	
grip strength	29.94±10.68	29.4±10.5	0.46
grip endurance	34.32±21.34	30.8±21.6	0.04
pinch strength	7.49±1.96	7.2±2	0.11
pinch endurance	33.50±22.31	33.52±23.4	0.99

DISCUSSION

In the present study, as shown in Table 2, there was a direct relationship between Vo_{2max} and factors including grip strength and endurance, pinch strength and endurance and BMI. Ranjana *et al.* carried out a study in 2015, comparing the grip strength and endurance between the two groups of obese young of 20 to 35 years (BMI> 30 kg / m^2) and none-obese young (18.5<BMI <25 kg / m^2). In young-obese, do was, comparing to the none-obese young, there seemed to be seven percent increase in grip strength; 32% reduction in endurance period; 34% decline in the rate of power-loss, there was also an increase in RPE. However, they did not observe any of the abovementioned factors in elderly-obese (over 50 years) [22]. Rangana [22] and Cavuuoto [24] study Similar to the present study However, in 2004, Rolland *et al.* observed no difference between the hand grip strength of elderly-obese and non-obese elderly [25]. Eksioglu reported an inverse relationship between BMI and grip endurance [26]. Habibi *et al.* was shown that pinch and grip strength in the dominant hand is more than that of the non-dominant. Moreover, a significant relationship was reported to exist between BMI in dominant and non- dominant grip and pinch strength [27]. In the present study grip and pinch strength and their endurance were not significantly different before and after the Step test. It can be due to the lack of involvement of upper body muscles in this test. Rantanen *et al.* focused their study on men of 50-68 years and found the average maximum grip strength of 36.65 kgs [28]. In a study carried out by Shandir Ramlagan *et al.* in South Africa in 2014, 3840 men and women of 50 years and older were tested. The average grip strength was 37.9 kg for men with a mean age of 61 years and 31.5 kg for women with an average age of 62 years. Moreover, in their study, grip strength was found to have a meaningful relationship with height[16]. The results of Hairi *et al.* also supported their findings[29]. Our study also found a significant relationship between height and pinch grip strength (i.e. grip and pinch strength in taller participants were higher). However, no significant relationship was found to exist between the heights of participants and their grip and pinch endurance. In a study carried out by Victoria and coworkers in 2015 on 741 boys and 767 girls aged 6-19. It was observed that gender and age have an influence on hand strength. On the basis of the findings, hand grip strength rises as the age of participants increase. There seems to be a direct relationship between hand grip strength and the age of participants. Moreover, boys' hand grip strength ate higher than that of girls. But the dominant hand showed no significant effect [23]. Habibi and coworkers in their study found no significant relationship between age and grip and pinch strength [27]. However, in the present study, it was observed that there are direct relationships between age and factors such as grip strength, pinch strength, grip endurance and pinch endurance. Mathiowetz [30] and Ager [31] reported gender as an important factor affecting hand strength, while Butterfield pointed out that gender is significant only for children over12. As he confirmed, hand power depends on both gender and age [32]. In the study carried out by Nicola *et al.* the weakest grip strength was related to with high BMI who were either under 30 or over 70, while the highest grip strength was related to those with high BMI who were between 30-70 years [12].

CONCLUSIONS

Vo_{2max} is known as an effective factor influencing on grip endurance. Also, Vo_{2max} seems to have a direct

relationship with grip strength and endurance, pinch strength and endurance and BMI. Therefore, in jobs that require high grip and pinch strength and endurance employed those with high Vo_{2max} so that WMSDs would be prevented. The present study only included male students and office workers; therefore, it is highly recommended to carry out research including female and industrial workers by consideration kind of work, working physically and overall physical activity. Moreover, it is suggested that other methods be used to assess Vo_{2max} and examine simultaneously the influence of age, obesity and height on Vo_{2max} and grip strength and endurance, pinch strength and endurance.

ETHICAL ISSUES

The Isfahan University of medical sciences ethics committee approved the study protocol (Ethics Code= IR.MUI.REC.1395.1.091).

CONFLICT OF INTERESTS

There are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

All authors equally helped to write this manuscript.

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