ORIGINAL ARTICLE

Bali Medical Journal (*Bali Med J)* 2020, Volume 9, Number 3: 823-829
P-ISSN.2089-1180, E-ISSN: 2302-2914

Published by DiscoverSys

The analysis of hand maximum voluntary contraction and its associated factors among hemodialysis-dependent chronic kidney disease patient in Jordan

Hesham A. Almomani[1*], Thaker Almomani[2], Marya Almomani[3], Soha Kana'an[4], Ahmed Al-Khawaldeh[1]

ABSTRACT

Introduction: Maximum voluntary contraction (MVC) of handgrip strength is considered a reliable subjective global assessment tool and has been used as predictive tools for human body performance. The usefulness MVC for continuous assessment of muscle strength in chronic kidney disease (CKD) patient's hemodialysis patients need to be investigated.

Methods: The research involved 100 CKD patients that underwent routine hemodialysis in Jordan. The subject's demographic and anthropometric data were collected. Subjects also tested for MVC using a dynamometer. The data was analyzed to find the relationship between each of the independent factors, including age, body mass index (BMI), handgrip circumference (HGC), forearm circumference (FAC), to the maximum voluntary contraction (MVC). Linear and nonlinear modeling were generated to estimate the effect of each independent variable.

Results: Subjects ages varied from 20-70 years old, for males mean age was 46.48 years old, mean weight 83.74 kg, mean height 167.24 cm, mean BMI 30.28 kg/m^2, mean handgrip circumference 21.34 cm, and mean forearm circumference 26.13 cm. For females, the mean age was 47.62 years old, weight 77.28 kg, mean height 162.96 cm, mean BMI 29.24 kg/m^2, mean handgrip circumference 20.09 cm, and mean forearm circumference 24.83 cm. For males, the highest MVC Value was 49.3 lbf, while for females, the highest MVC Value was 38.6 lbf, and both from the group aged <30 years old. ANOVA revealed that age was the primary factor that was significantly associated with MVC.

Conclusion: The age has major and significant effects on maximum voluntary contraction in CKD patients.

Keywords: Haemodialysis, Maximum Voluntary Contraction, Handgrip strength

Cite this Article: Almomani, H.A., Almomani, T., Almomani, M., Kana'an, S., Al-Khawaldeh, A. 2020. The analysis of hand maximum voluntary contraction and its associated factors among hemodialysis-dependent chronic kidney disease patient in Jordan. *Bali Medical Journal* 9(3): 823-829. DOI: 10.15562/bmj.v9i3.1820

[1]Department of Industrial Engineering, Faculty of Engineering, The Hashemite University, Jordan
[2]Department of Biomedical Engineering, Faculty of Engineering, The Hashemite University, Jordan
[3]Faculty of Medicine, The Hashemite University, Jordan
[4]Royal Medical Services Department, Jordan army, Amman, Jordan

*Corresponding to:
Hesham A. Almomani; Department of Industrial Engineering, Faculty of Engineering, The Hashemite University, Jordan;
Heshamalmomani@hu.edu.jo.

Received: 2020-05-11
Accepted: 2020-07-23
Published: 2020-12-01

INTRODUCTION

Chronic kidney disease patients relatively hypoactive, have reduced exercise capacity and decreased physical functioning compared to the general healthy people. Impaired physical functioning is associated with a low quality of life and high mortality in this population. Also, there is a strong relationship between nutrition and outcomes of hemodialysis patients due to inflammations occurred during dialysis sessions.[1] However, muscle abnormalities likely contribute to this problem.

The researcher can measure the strength of muscles before and after the hemodialysis treatment by using the handgrip strength (HGS), which is defined as the force applied by the hand to pull on or suspend objects and is a specific part of hand strength.[2] The highest amount of tension a muscle can produce and sustain in a specific isometric exercise is called the Maximum Voluntary Contraction (MVC). Most of the researchers used the dynamometer to test MVC and readings, usually taken as the maximum value of three efforts in a single test trial.

There are many recommendations to consider that HGS is a critical aspect of general geriatrics screening in clinical settings. HGS also potentially useful for the diagnostic parameter to measures the general level of health of the human body, as well as the upper part of the body.[3] This method is beneficial, particularly during HD sessions, as it can measure the strength of muscles without interfering with the sessions.[4] HGS, which reflects muscle function, is considered one of the most reliable indicators of nutritional status alterations due to its rapid, inexpensive, and non-invasive characteristics. Therefore, it has been adopted as a subjective global assessment for muscles.[5] Previous study has evaluated the independent prognostic importance of handgrip strength in multicultural, economically varied countries and stated that grip strength measurement is a simple, affordable, risk-free method to predict all-cause death, cardiovascular death, and cardiovascular disease.[6] Although HGS is a straight-forward parameter, it is undoubtedly influenced by many other conventional biological parameters such as age, gender, and anthropometric-related factors. Not to mention that we also have to consider the contribution of a specific disease and medical treatment, such as chronic kidney disease and hemodialysis. Due to the trend observed recently, the author believed that many types of research had performed the measurement of MVC and the associated predictor. However, most resulted in only specific (one or two factors) and not intended to build a comprehensive model that include all parameters to predict the handgrip strength either for complete or submaximal voluntary contraction.[7] Thus, this study aims to fulfill the gap and deepen the understanding of HGS and the associated factors in the population of chronic kidney disease that underwent regular hemodialysis treatment.

METHODS

This study was held in Jordan. It included 100 patients (54 female and 46 male) with chronic kidney disease on regular hemodialysis. The sample included only patients that live an independent, regular life activity with age ranging between 20 and 70 years old. This study employed a concept of psychophysical approach. The psychophysical approach depends on human subject judgment and rating of stress on their joints and muscles. According to Snook, the psychophysical approach includes the individual subjective rating to evaluate the fatigue of different body parts, particularly the muscles and joints.[8]

This study investigates the effect and relationship of seven independent factors, including age, body mass index (BMI), handgrip circumference (HGC), hand dominancy, forearm circumference (FAC), and the maximum voluntary contraction (MVC). The variables classification is provided in Table 1. Maximum voluntary contraction measured using the Handgrip dynamometer involving dominant hands. The study was designed to enable patients to participate in a study at one time and under the standardized condition. Study have been in accordance to Hashemite University Regulation.

The measurement results were analyzed statistically and continued with the construction of a mathematical model. Study results were analyzed in the following step. First, the data underwent descriptive statistics analysis. It was then continued with the correlation analysis, normality test, outlier analysis, and ANOVA. Linear and nonlinear regression models were developed and compared. All analyses were conducted in Mini tab 17.

Table 1. Variable Classification

Dependent Variables	Independent Variables	Variable Levels
VC Fixed Factors Jordanian Subjects Digital Dynamometer	Age (years)	A0: (25-<30) A1: (30-<35) A2: (35-<40) A3: (40-<45) A4: (45-<50) A5: ≥50
	Body Mass Index (BMI)	1) Small: S (19-<25) 2) Medium: M (25-<30) 3) Large: L above =>30
	Hand Grip Circumference (CM)	1) Small: S (=< 21.5) 2) Medium: M (>21.5 -23.5) 3) Large: above 23.5
	Forearm Circumference (FAC)	1) Small: S (<= 27.5) 2) Medium: M (>27.5-31) 3) Large: (above 31)
	Height (M)	1) Short: S (<= 1.70) 2) Medium: M (>1.70-1.81) 3) Tall: T (above 1.81)

RESULT

Subjects group ages varied from 20-70 years old. The analysis emphasizes gender, as it is the basic, biologically-relevant classification of the human being. For males, the highest MVC Value was 49.3 lbf from the sample of A0 age groups, and the lowest MVC Value was the A4 group, which was 38.5 lbf. For females, the highest MVC Value was for the A0 age group, 38.6 lbf, and the lowest MVC value was A4 sample group 22.1 lbf. Table 2 below shows the descriptive statistics for all independent variables.

Table 3 showed the ANOVA results for males and females. Model adequacy checks were tested for MVC data and found that assumptions met for homogeneity of variance, normality, and independency. ANOVA, with a 95% confidence level, was used to test the effects of the independent factors considered the overall situation of hemodialysis patient's status.

ANOVA revealed that age was the primary factor that was significantly associated with MVC. The non-significant factors were BMI, height, weight, HGC, and FAC. The linear and nonlinear model for the prediction of MVC is constructed from all variables provided in table 4 below. Table 6 shows the general linear equations for Max MVC

Published by DiscoverSys | *Bali Med J* 2020; 9(3): 823-829 | doi: 10.15562/bmj.v9i3.1820

Table 2. Descriptive statistics of MVC

Variable	Gender	Count	Mean	StDev	Minimum	Maximum
Age	F	54	47.39	12.78	21.00	84.00
	M	46	46.48	12.93	24.00	70.00
Height	F	54	163.11	9.10	146.00	182.00
	M	46	167.24	11.51	145.00	182.00
Weight	F	54	77.15	18.90	42.00	110.00
	M	46	83.74	19.53	45.00	112.00
HGC	F	54	20.13	2.07	17.00	24.00
	M	46	21.34	2.02	18.00	26.00
FAC	F	54	24.82	2.60	20.00	29.00
	M	46	26.13	2.63	22.00	32.00
Max MVC	F	54	19.62	8.61	6.40	44.00
	M	46	33.71	9.00	14.20	49.30

F: Female, M: Male, StDev: Standard Deviation

Table 3. Factorial ANOVA

		DF	*ADJ SS*	*ADJ MS*	*F-Value*	*P-Value*
Male						
	BMI	1	1.13	1.13	0.79	0.380
	Age	1	6.10	6.10	36.64	<0.0001
	Height	1	1.74	1.74	1.05	0.380
	Weight	1	77.4	77.38	2.02	0.516
	HGC	1	69.4	69.48	1.81	0.465
	FAC	1	2.7955	2.7955	1.68	0.203
	Error	39	64.94			
	Total	45	14.49			
Female						
	BMI	1	1.112	1.112	2.74	0.108
	Age	1	16.33	16.33	39.48	<0.0001
	Height	1	1.132	1.132	1.05	0.105
	Weight	1	77.4	77.38	2.74	0.121
	HGC	1	0.681	0.681	1.65	0.206
	FAC	1	0.0001	0.0001	0.00	0.991
	Error	46	19.028			
	Total	52	37.985			

with age effect.

DISCUSSION

The study was conducted with a psychophysical approach to examine the effect of static/dynamic forces on the handgrip maximum voluntary contraction (MVC) in CKD subjects. In this research, five independent factors are considered, most likely to represent all possible factors considered by other researchers during the last 60 years. Additionally, this study used the new apparatus (digital dynamometer) and cover a broader range of age groups, from 20 to 70 years old.

Grip strength can vary due to many factors, such as gender and age. Analysis of grip strength shows higher grip strength by males at all ages. Studies show that the strength of hand grip is much higher in men before hemodialysis than after it, but on the other side, there is no difference in women before and after HD sessions.[9] The decline in HGS for men came earlier than women (in men appears in 30 years but in women appears in 50 years.[10] Another research result shows that young males have higher HGS than females and even female athletes who have higher HGS but still less than the non-athletic male category. A previous study involving healthy Iranian subjects aged (20-60) years found that older people have lower handgrip strength than the younger. A study showed how handgrip dynamometry could predict future aging for adults, the result of those research shown a strong relationship between the low handgrip strength and the period in which the handgrip dynamometry needs to be also taken as a sign for mortality.[4]

Many previous studies have found a positive relationship of HGS with height, weight, and body mass index (BMI).[2,4,11] Many studies were also conducted to show a relationship between the handgrip strength and the dominant hand (use right or left hand as a dominant hand). They found that dominant hand strength is similar for both left and right hand.[12,13] Except for patients undergoing long-term hemodialysis, the HGS of the dominant hand was higher than the non-dominant hand. That result encourages the application of hand exercise in patients who underwent routine hemodialysis.[14] Some studies also showed that handgrip dynamometry could be a predictor for mortality.[4]

One other important factor that was found in many CKD patients that associate with handgrip strength and muscle function was nutritional status. Handgrip strength was a useful parameter of muscle mass, which related to nutritional status in patients on dialysis.[9] Overall, all study indicate that handgrip strength could be integrated into clinical practice for assessing nutrition status and prognosis of CKD patients.[15]

In contrast to many studies in the literature, this research considers all factors which might have a significant effect. Both linear and nonlinear modeling for each independent factor performed.

Table 4. The Linear and Nonlinear Equations to predict MVC

Linear Model (Males)	MVC -28.6 - 0.5333 Age + 0.359 Height (cm) - 0.177 Weight + 0.78 BMI + 0.558 FAC (cm) + 0.201 HGC (cm).
Linear Model (Females)	MVC =-74.2 -0.3783 Age + 0.597 Height (cm) - 0.633 Weight + 1.69 BMI + 0.637 HGC (cm) + 0.027 FAC (cm).
Nonlinear Models (Males)	MVC = -0.00652058 * Age ^ 2 + 0.00171065 * 'Height(CM)' ^ 2 - 0.00320711 *Weight ^ 2 + 0.0167954 * BMI ^ 2 + 0.01944 * 'HGC(CM)' ^ 2 + 0.00526857 * 'FAC(CM)' ^ 2 + 7.70356e-010 * Age * 'Height(CM)' * Weight * BMI * 'HGC(CM)' * 'FAC(CM)' - 19.2432
Nonlinear Models (Female)	MVC = -11.51 - 0.05254 Age + 0.0766 Height (CM) - 0.0570 Weight + 0.1758 BMI + 0.1105 HGC (CM) + 0.0550 FAC (CM)

Table 5. Effect of Age, Height, BMI, HGC, FAC Values on MVC

Variable	Category	Mean (min-max)		Linear Equation
		Male	Female	
Age	A0: (25-<30)	40.50 (35.10 – 45.60)	25.27 (18.10 – 35.40)	Male: MVC = 130.6 - 0.401 Height + 0.537 Weight - 1.153 BMI - 0.467 HGC + 0.596 FAC - 1.434 Age Female: MVC =-112.4 - 0.283 Age + 0.770 Height - 0.848 Weight + 2.30 BMI + 0.535 HGC + 0.208 FAC
	A1: (30-<35)	43.37 (39.40 – 49.30)	26.77 (18.30 – 38.60)	Male: MVC = 143.8- 0.401 Height + 0.537 Weight - 1.153 BMI - 0.467 HGC + 0.596 FAC - 1.434 Age Female: MVC = -105.9 - 0.283 Age + 0.770 Height - 0.848 Weight + 2.30 BMI+ 0.535 HGC + 0.208 FAC
	A2: (35-<40)	32.78 (27.80 – 38.50)	21.14 (15.30 – 26.40)	Male: MVC = 137.8 - 0.401 Height + 0.537 Weight - 1.153 BMI - 0.467 HGC + 0.596 FAC - 1.434 Age Female: MVC = -110.5 - 0.283 Age + 0.770 Height - 0.848 Weight + 2.30 BMI+ 0.535 HGC + 0.208 FAC
	A3: (40-<45)	37.70 (35.20 – 40.20)	20.41 (12.30 – 29.40)	Male: MVC = 154.1- 0.401 Height + 0.537 Weight - 1.153 BMI - 0.467 HGC + 0.596 FAC - 1.434 Age Female: MVC = -109.7- 0.283 Age + 0.770 Height - 0.848 Weight + 2.30 BMI+ 0.535 HGC + 0.208 FAC
	A4: (45-<50)	35.87 (27.60 – 44.60)	21.01 (12.30 – 31.70)	Male: MVC = 154.8- 0.401 Height + 0.537 Weight - 1.153 BMI - 0.467 HGC + 0.596 FAC - 1.434 Age Female: MVC = -108.5 - 0.283 Age + 0.770 Height - 0.848 Weight + 2.30 BMI+ 0.535 HGC + 0.208 FAC

Published by DiscoverSys | *Bali Med J* 2020; 9(3): 823-829 | doi: 10.15562/bmj.v9i3.1820

Variable	Category	Mean (min-max)		Linear Equation
		Male	Female	
	A5: (Above 50)	29.33 (9.40 – 45.70)	14.07 (6.40 – 22.10)	Male: MVC = 163.3- 0.401 Height + 0.537 Weight - 1.153 BMI - 0.467 HGC + 0.596 FAC - 1.434 Age Female: MVC = -112.7 - 0.283 Age + 0.770 Height - 0.848 Weight + 2.30 BMI+ 0.535 HGC + 0.208 FAC
Height	Short (<= 1.70)	33.63 (14.20 – 45.60)	17.90 6.40 – 35.40	Male: MVC = -11.8+ 0.258 Height- 0.130 Weight + 0.64 BMI + 0.007 HGC + 0.626 FAC - 0.4975 Age Female: MVC = -11.8 - 0.3415 Age + 0.214 Height - 0.417 Weight + 1.19 BMI + 0.495 HGC- 0.073 FAC
	Medium (>1.70-1.81)	35.37 (9.40 – 49.30)	24.35 (12.20 – 38.60)	Male: MVC = -10.0 + 0.258 Height- 0.130 Weight + 0.64 BMI + 0.007 HGC + 0.626 FAC - 0.4975 Age Female: MVC = -5.0 - 0.3415 Age + 0.214 Height - 0.417 Weight + 1.19 BMI + 0.495 HGC- 0.073 FAC
	Tall (above 1.81)			Male: MVC = -20.7 + 0.258 Height- 0.130 Weight + 0.64 BMI + 0.007 HGC + 0.626 FAC - 0.4975 Age Female: MVC = -10.3 - 0.3415 Age + 0.214 Height - 0.417 Weight + 1.19 BMI + 0.495 HGC- 0.073 FAC
BMI	19-<25 kg/m^2	33.51 (14.20 – 49.30)	21.17 (7.40 – 38.60)	Male: MVC = -31.9 + 0.403 Height - 0.195 Weight + 0.80 BMI + 0.129 HGC + 0.490 FAC - 0.5292 Age Female: MVC =-42.4 - 0.3742 Age + 0.326 Height - 0.278 Weight + 1.423 BMI+ 0.698 HGC - 0.042 FAC
	25-<30 kg/m^2	31.51 (9.40 – 41.80)	19.25 (6.40 – 31.70)	Male: MVC = -33.3 + 0.403 Height - 0.195 Weight + 0.80 BMI + 0.129 HGC + 0.490 FAC - 0.5292 Age Female: MVC =-47.5 - 0.3742 Age + 0.326 Height - 0.278 Weight + 1.423 BMI+ 0.698 HGC - 0.042 FAC
	≥ 30 kg/m^2	35.87 (15.00 – 45.70)	17.73 (7.20 – 35.40)	Male: MVC = -31.1 + 0.403 Height - 0.195 Weight + 0.80 BMI + 0.129 HGC + 0.490 FAC - 0.5292 Age Female: MVC = -54.6 - 0.3742 Age + 0.326 Height - 0.278 Weight + 1.423 BMI+ 0.698 HGC - 0.042 FAC

Variable	Category	Mean (min-max)		Linear Equation
		Male	Female	
HGC	≤ 21.5	34.22 (15.00 – 49.30)	18.88 (6.40 – 38.60)	Male: MVC = -30.4 + 0.419 Height - 0.235 Weight + 0.90 BMI - 0.28 HGC + 0.622 FAC - 0.5329 Age Female: MVC =-78.7 - 0.3797 Age + 0.572 Height - 0.612 Weight + 1.63 BMI + 1.086 HGC + 0.046 FAC
	>21.5 -23.5	35.27 (9.40 – 45.60)	19.36 (7.40 – 35.40)	Male: MVC = -27.3 + 0.419 Height - 0.235 Weight + 0.90 BMI - 0.28 HGC + 0.622 FAC - 0.5329 Age Female: MVC =-81.7 - 0.3797 Age + 0.572 Height - 0.612 Weight + 1.63 BMI + 1.086 HGC + 0.046 FAC
	> 23.5	31.89 (14.20 – 45.70)	20.28 (8.40 – 31.70)	Male: MVC = -28.5 + 0.419 Height - 0.235 Weight + 0.90 BMI - 0.28 HGC + 0.622 FAC - 0.5329 Age Female: MVC = -80.9 - 0.3797 Age + 0.572 Height - 0.612 Weight + 1.63 BMI + 1.086 HGC + 0.046 FAC
FAC	≤ 27.5	32.45 (9.40 – 49.30)	19.20 (6.40 – 38.60)	Male: MVC = 10.6 + 0.290 Height - 0.082 Weight + 0.55 BMI - 0.079 HGC - 0.383 FAC - 0.5412 Age Female: MVC =-76.6 - 0.3847 Age + 0.572 Height- 0.600 Weight + 1.61 BMI+ 0.677 HGC + 0.278 FAC
	>27.5-31	36.74 (14.20 – 45.70)	18.70 (7.40 – 31.70)	Male: MVC = 16.2 + 0.290 Height - 0.082 Weight + 0.55 BMI - 0.079 HGC - 0.383 FAC - 0.5412 Age Female: MVC =-78.7 - 0.3847 Age + 0.572 Height- 0.600 Weight + 1.61 BMI+ 0.677 HGC + 0.278 FAC
	> 31	44.60 (44.60-44.60)		Male: MVC = 22.1 + 0.290 Height - 0.082 Weight + 0.55 BMI - 0.079 HGC - 0.383 FAC - 0.5412 Age

All independent factors had correlation effects as expected since most related to subjects' physical factors (of the human body) such as height, weight, and body mass index. Overall, the correlation between age and height to MVC was negative. Meanwhile, the correlation between BMI to MVC was positive.

The limitation of the study is related to the difficulty of recruiting patients. Also, there is a difficulty in encouraging patients to do the contraction test. In the future, studies with larger samples and more parameters are needed. It can include the effects of nutritional status and race. Also, we encourage studies that investigate the MVC in other diseases such as diabetes, heart diseases, osteoporosis, and asthma. Lastly, improvement in accuracy could be achieved by the model generated from the Neural Network and other advanced computation techniques.

Published by DiscoverSys | *Bali Med J* 2020; 9(3): 823-829 | doi: 10.15562/bmj.v9i3.1820

CONCLUSION

Age was the primary factor that was significantly associated with MVC. The uniqueness and significance of the research illustrated in the reliability of handgrip strength as an essential sign of general health, including in CKD patients. Whereas the results from this research verify other researchers work, it also proposes comprehensive models considering six different independent factors.

AUTHOR CONTRIBUTION

All authors contributed equally in all phases of the study.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

FUNDING

The author(s) received no financial support for the research, authorship, and/or publication of this article.

REFERENCE

1. Rashid Qureshi A, Alvestrand A, Divino-Filho JC, et al. Inflammation, malnutrition, and cardiac disease as predictors of mortality in hemodialysis patients. *J Am Soc Nephrol*. 2001;13(SUPPL. 1):28-36.
2. Koley S, Kaur N, Sandhu JS. A Study on Hand Grip Strength in Female Labourers of Jalandhar, Punjab, India. *J Life Sci*. 2009;1(1):57-62. doi:10.1080/09751270.2009.11885135
3. Sirajudeen M, Shah U, Pillai P, Mohasin N, Shantaram M. Correlation between Grip Strength and Physical Factors in Men. *Int J Heal Rehabil Sci*. 2012;1(2):58. doi:10.5455/ijhrs.000000010
4. Bohannon RW. Hand-Grip Dynamometry Predicts Future Outcomes in Aging Adults. *J Geriatr Phys Ther*. 2008;31(1):3-10. doi:10.1519/00139143-200831010-00002
5. Carrero JJ, Stenvinkel P, Cuppari L, et al. Etiology of the Protein-Energy Wasting Syndrome in Chronic Kidney Disease: A Consensus Statement From the International Society of Renal Nutrition and Metabolism (ISRNM). *J Ren Nutr*. 2013;23(2):77-90. doi:10.1053/j.jrn.2013.01.001
6. Leong DP, Teo KK, Rangarajan S, et al. Prognostic value of grip strength: findings from the Prospective Urban Rural Epidemiology (PURE) study. *Lancet*. 2015;386(9990):266-273. doi:10.1016/s0140-6736(14)62000-6
7. Almomani HA. A Psychophysical Approach For Predicting Isometric And Isotonic Hand Muscle Strength In The Aviation Industry. 2015. https://eis.hu.edu.jo/deanshipfiles/pub11278100052.pdf.
8. Snook SH. The Ergonomics Society The Society's Lecture 1978. THE DESIGN OF MANUAL HANDLING TASKS. *Ergonomics*. 1978;21(12):963-985. doi:10.1080/00140137808931804
9. Leal VO, Stockler-Pinto MB, Farage NE, et al. Handgrip strength and its dialysis determinants in hemodialysis patients. *Nutrition*. 2011;27(11-12):1125-1129. doi:10.1016/j.nut.2010.12.012
10. Kalyani RR, Kim C, Ferrucci L, et al. Sex differences in the association of fasting and post-challenge glucose levels with grip strength among older adults: the Rancho Bernardo Study. *BMJ open diabetes Res care*. 2015;3(1):e000086-e000086. doi:10.1136/bmjdrc-2015-000086
11. Fogelholm M, Malmberg J, Suni J, et al. International Physical Activity Questionnaire. *Med Sci Sport Exerc*. 2006;38(4):753-760. doi:10.1249/01.mss.0000194075.16960.20
12. De Andrade Fernandes A, Natali AJ, Vieira BC, et al. The relationship between hand grip strength and anthropometric parameters in men. *Arch Med del Deport*. 2014;31(161):160-164.
13. Cheung CL, Nguyen USDT, Au E, Tan KCB, Kung AWC. Association of handgrip strength with chronic diseases and multimorbidity: A cross-sectional study. *Age (Omaha)*. 2013;35(3):929-941. doi:10.1007/s11357-012-9385-y
14. Limaye V, Frankham A, Disney A, Pile K. Evaluation of hand function in patients undergoing long term haemodialysis. *Ann Rheum Dis*. 2001;60(3):278-280. doi:10.1136/ard.60.3.278
15. Chang YT, Wu HL, Guo HR, et al. Handgrip strength is an independent predictor of renal outcomes in patients with chronic kidney diseases. *Nephrol Dial Transplant*. 2011;26(11):3588-3595. doi:10.1093/ndt/gfr013