UNIVERSITAT POLITÈCNICA DE CATALUNYA
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GRAU EN ÒPTICA I OPTOMETRIA

TREBALL FI DE GRAU

REPEATABILITY OF PUSH-UP AND PUSH-DOWN METHODS IN THE MEASURE OF ACCOMMODATION AMPLITUDE

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12 de Juny de 2017

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GRAU EN OPTICA I OPTOMETRIA

Els Srs. Jaume Pujol Ramo i Mikel Aldaba Arévalo, com a tutors i directors del treball,

CERTIFICA/CERTIFIQUEN

Que el Sr./Sra. Cinta Duatis Alcoverro ha realitzat sota la seva supervisió el treball "Repeatability of push-up and push-down methods in the measure of accommodation amplitude" que es recull en aquesta memòria per optar al títol de grau en Òptica i Optometria.

I per a què consti, signo/em aquest certificat.

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Terrassa, 12 de Juny de 2017

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RESUM

La mesura de l'amplitud d'acomodació és una pràctica molt habitual en optometria. La majoria de professionals coincideixen en que els mètodes push-up i push-down són els més utilitzats als exàmens visuals degut al fet que són mètodes ràpids, fàcils i eficaços. Tot i això, és important saber la concordança entre cada mètode per tal de realitzar diagnòstics correctes. En aquest estudi, s'han comparat els resultats en diòptries dels mètodes push-up i push-down. Per tal de dur a terme l'estudi, s'ha mesurat l'amplitud d'acomodació a 12 pacients, dues vegades, prenent 3 mesures en cada repetició. Per avaluar la concordança entre mètodes s'han utilitzat el paired-T test, el Shapiro-wilk test i el gràfics de Bland and Altman. L'anàlisi estadístic de les dades mesurades s'ha fet per tal d'estudiar ambdós mètodes. Els resultats no han mostrat diferències significatives entre el mètode del push-up i el del push-down.

La medida de la amplitud de acomodación es una práctica muy habitual en la optometría. La mayoría de profesionales coinciden en que los métodos del push-up y el push-down son los más utilizados en los exámenes visuales debido a su facilidad de ejecución y elevada eficacia. Sin embargo, es importante saber la concordancia que existe entre métodos para realizar diagnósticos correctos. En este estudio se han comparado los resultados en dioptrías de los métodos push-up y push-down. Para llevar a cabo el estudio, se han tomado medidas de amplitud de acomodación en 12 pacientes, dos veces, tomando 3 medidas en cada repetición. Para evaluar la concordancia entre métodos se han utilizado el paired-T test, el Shapiro-wilk test i los gráficos de Bland and Altman. El anàlisis estadístico de los datos tomados se ha realizado para estudiar ambos métodos.Los resultados no ha mostrado diferencias significantes entre el método del push-up y el método push-down.

Measuring the amplitude of accommodation is a common practice in clinical optometry. Many professionals accept that push-up and push-down methods are the most commonly performed during the examinations due to the fact that these are quick, cheap and easy-doing techniques. However, it is important to know the agreement between each method in order to make correct diagnosis. In this study results of amplitude of accommodation in diopters taken by means of push-up method and push down-method have been compared. So as to accomplish the study, accommodation amplitude of 12 right eyes have been measured twice, taking three data each time. The paired t-test, the Shapiro-Wilk test and the Bland and Altman plots have been used to assess the agreement between methods. Statistical analysis of the taken data was done in order to study both methods. The results showed no significant differences between push-up and push-down methods.

ABSTRACT.

Purpose: To measure the amplitude of accommodation as it is a common practice in clinical optometry. Many professionals accept that push-up and push-down methods are the most commonly performed during the examinations due to the fact that these are quick, cheap and easy-doing techniques. However, it is important to know the agreement between each method in order to make correct diagnosis.

Methods: In this study results of amplitude of accommodation in diopters taken by means of push-up method and push down-method have been compared. So as to accomplish the study, accommodation amplitude of 12 right eyes have been measured twice, taking three trials each time.

Results: 12 patients participated in the study. The mean age ± SD (standard deviation) was 24.17 ± 2.86 years. The paired t-test, the Shapiro-Wilk test and the Bland and Altman plots have been used to assess the agreement between methods. Statistical analysis of the taken data was done in order to study both methods. The results showed no significant differences between push-up and push-down methods.

Conclusions: Since push-up method results are very similar to the push-down results, this study would show that both methods have similar results and would not make clinically significant differences.

INTRODUCTION.

Since the use of digital displays have become much more common in our society, nowadays, near images can be experienced in our daily life in many different ways due to the fact they are available for viewing via various multimedia tools (1). That is the reason why an optimal visual function, especially at near distance, has acquired more importance than in the past. Accommodation problems are a common cause of vision fatigue, or ocular asthenopia, especially in adolescents and young adults (2) and management of these conditions is primordial in optometry

Accommodation is the process in which the eyes change the dioptric power in order to focus stimuli at different distances. It is generally accepted that it involves the ciliary muscle, the zonule of Zinn and the human lens. When the stimulus is situated at far vision, which means that the accommodative system is relaxed, the eye does not need extra power to focus it, then the ciliary muscle is relaxed, the zonule of Zinn fibres are tensed and the human lens is in rest position (≈15D). On the other hand, when the stimulus is situated at near vision, the ciliary muscle is stretched, the zonule of Zinn fibres relax and the curvature of the anterior surface of the human lens increases. As a result, its dioptric power also increases and the image of a near object is focused on the retina (3).

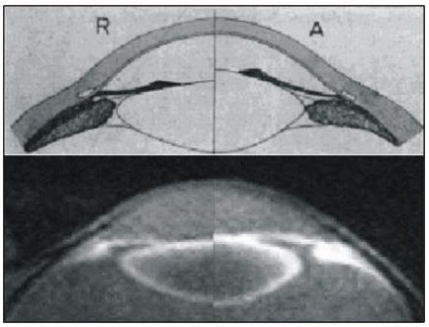

Figure 1. The upper part shows the human lens relaxed (R) and accommodating (A). The lower part is a magnetic resonance of the eye showing the same comparison (4).

The nearer the object is the more power of human lens (accommodation) is required and, therefore, the curvier the lens becomes (Figure 1).

Accommodative response depends on factors like observation distance, object size and individual age (5),(6). The accommodative system, as other mechanisms of the human body, loses properties as it gets old. As a result, accommodation decreases as individuals mature (Table 1) and presbyopia appears (7). According to several studies, the amplitude of accommodation decreases continuously around 0.3D per year and people develop presbyopia at the age of 40 years approximately (7).

It is considered that a person who has presbyopia is an individual whose amplitude of accommodation is not enough to see sharp the stimuli presented at near vision. As a consequence, the presbyopic subjects need a positive power addition in order to focus objects at near distance.

Table 1. Based age Donders' table for accommodation amplitude (AA) (5).

Age (years)	AA(Diopters)	Age (years)	AA(Diopters)	Age (years)	AA(Diopters)
1	18.00	30	7.00	55	1.75
10	14.00	35	5.50	60	1.00
15	12.00	40	4.50	65	0.50
20	10.00	45	3.50	70	0.25
25	8.50	50	2.50	75	0.00

The quantity of accommodation that an individual is able to hold is descripted as Accommodation Amplitude (5). This magnitude defines the maximum change of power that the human lens can afford in order to see properly near objects. It is defined as the difference between the remote point (PR) (point in the real space which is conjugated with the fovea when the accommodation is relaxed) and the near point (PP) (point in the real space which is conjugated with the fovea when the eye is in its maximum accommodation state). AA measurements reflect the maximum capacity a subject has to stimulate his accommodative response (2).

The average AA at any age can be approximated by the equation (5)

$$\text{AA} = 18.5 - \frac{1}{3}\,\text{age}$$

The minimum amplitude of accommodation expected for a given age can be calculated as (8)

$$AA_{min} = 15 - \frac{1}{4}\,\text{age}$$

The most commonly used techniques to measure the amplitude of accommodation in clinics are Sheard's and Donders' methods. The first one consists in adding negative lenses when the subject is looking with his subjective refraction at a stimulus situated at 40cm until he reports blur vision. The second one is also called push-up method. It consists in moving closer a test towards the patient, who is wearing the subjective refraction, until he reports blur vision. The push-down method consists in beginning with the test as closer as the patient is not able to see it properly and distancing it until he reports clear vision. All methods are done monocularly (5).

The accommodative facility evaluates the ability of the visual system to change the accommodative state. It is typically measured as the number of times the subject can change the accommodative state in a minute using flipper of lenses with +/- 2D. It can be measured at far and at near vision, monocularly and binocularly. There are more parameters related to accommodation, such as the negative relative accommodation (NRA) and the positive relative accommodation (PRA).

NRA can be defined as the ability to relax accommodation while maintaining clear, single binocular vision. On the other hand, PRA corresponds to the ability to stimulate accommodation while maintaining clear, single binocular vision.

When accommodating, human visual system also converge due to the near vision complex (8). The linkage between the vergence and accommodation systems is measured by means of the accommodative convergence-accommodation (AC/A) ratio.

The most common anomalies of accommodation are accommodative insufficiency, accommodative excess, accommodative infacility.

Accommodative insufficiency is a condition in which the patient has difficulty stimulating accommodation. The characteristic finding is an accommodative amplitude 2D or more below the lower limit of the expected value for the patient's age (8). Despite the fact that symptoms are identical, it is important to differentiate between accommodative insufficiency and presbyopia considering that the second one is not a dysfunction but a characteristic physiological effect and that presbyopic people have an expected AA value.

Accommodative excess is a circumstance that makes the fact of relaxing accommodation a difficulty (8). This dysfunction is characterized by an accommodative response exceeding the accommodative stimulus. Most symptoms are associated with reading or other close works and patients typically report headache, photophobia, blurred vision, eyestrain, etc. The sings are difficulty clearing +2.00D lens during monocular accommodative facility test, low monocular estimation method (MEM) retinoscopy finding, reduced NRA, etc.

Accommodative infacility is a limitation of the change of the accommodative response level. It is a condition in which the latency and speed of the accommodative response are abnormally larger while the AA is normal. (9). Most symptoms are similar to the dysfunctions named before. The clinical signs of accommodative infacility are: difficulty clearing -2.00 D and +2.00 D with monocular or binocular accommodative facility. In case of abnormal results of binocular accommodative facility, it might be related to some vergence problem and not only accommodative.

The aim of this study is to compare the push up method and push down method when measuring the amplitude of accommodation. The agreement between both methods will be analysed and also its repeatability.

METHODOLOGY.

12 patients participated in the study. The mean age ± SD (standard deviation) was 24.17 ± 2.86 years (range from 21 to 29 years). The visual acuity in near vision was equal or greater than 20/20 with their habitual correction. The refractive error of patients ranged from -6.75 D to 0.00 D.

The amplitude of accommodation of the right eye was collected using two common clinical techniques: push-up and push-down methods. The patients were examined by means of an accommodative target with a visual acuity 20/25 and maximum lighting. In the first measure (the push-up method) the examiner moved closer a test towards the patient, who was wearing the subjective refraction until the patient reported blur vision. In the second measure (the push-down method) the examiner began with the test as closer as the patient was not able to see it properly and distancing it until he reported clear vision. The distance taken while using these methods was related to amplitude of accommodation by the inverse of the distance in meters. Both methods were performed twice by the same examiner taking three measures of each method every time. The time between the first and the second measures were between 3 hours and 12 days.

The statistical analysis was performed using the SPSS software version 22.0. The Shapiro-Wilk test was used to check the normality of the variables. The paired t-test and the Bland and Altman plots were used to analyse the repeatability of both methods. Significance was set at $p<0.05$.

RESULTS.

First, the taken measures by the methods are shown in in tables 1 and 3. Descriptive data (mean, SD) from the analysed methods are shown in tables 2 and 4.

Table2. Push-up method results.

Pacient ID	Moment	Push up (D)			Mean	Moment 1&2 mean
1	1	8,33	8,70	8,00	8,33	9,25
	2	10,53	10,00	10,00	10,17	
2	1	11,11	10,53	11,11	10,91	11,22
	2	11,11	12,50	11,11	11,54	
3	1	12,50	13,33	14,29	13,33	13,98
	2	15,38	14,29	14,29	14,63	
4	1	8,70	8,70	8,33	8,57	8,51
	2	8,33	9,09	8,00	8,45	
5	1	9,09	9,52	10,00	9,52	9,60
	2	10,00	9,52	9,52	9,68	
6	1	10,53	11,11	11,76	11,11	12,08
	2	13,33	12,50	13,33	13,04	
7	1	12,50	12,50	13,33	12,77	12,27
	2	11,76	11,76	11,76	11,76	
8	1	9,09	9,09	9,09	9,09	9,38
	2	10,00	9,09	10,00	9,68	
9	1	12,50	10,53	9,52	10,71	11,48
	2	11,76	10,00	16,67	12,24	
10	1	9,52	10,00	9,52	9,68	9,12
	2	8,33	8,33	9,09	8,57	
11	1	10,00	11,11	11,11	10,71	11,02
	2	11,11	11,11	11,76	11,32	
12	1	11,11	10,00	10,53	10,53	11,65
	2	12,50	12,50	13,33	12,77	

Table 3. Mean and SD of the push-up method.

	Mean	SD
Mean	10,80	1,63
Moment 1	10,44	1,53
Moment 2	11,15	1,89

Table 4. Push-down method results.

Patient ID	Moment	Push down (D)			Mean	Moment 1&2 mean
1	1	8,00	8,33	8,00	8,11	8,29
	2	8,33	9,09	8,00	8,47	
2	1	10,00	9,52	10,26	9,93	9,52
	2	9,09	8,70	9,52	9,10	
3	1	14,29	14,29	13,33	13,97	14,49
	2	15,38	14,29	15,38	15,02	
4	1	8,00	8,33	8,33	8,22	8,88
	2	10,00	9,09	9,52	9,54	
5	1	8,33	8,33	8,33	8,33	9,57
	2	9,52	11,11	11,76	10,80	
6	1	10,53	11,11	11,76	11,13	13,26
	2	15,38	15,38	15,38	15,38	
7	1	12,50	12,50	13,33	12,78	11,65
	2	10,53	10,53	10,53	10,53	
8	1	9,09	9,52	10,00	9,54	9,77
	2	10,00	10,00	10,00	10,00	
9	1	11,76	11,76	11,76	11,76	11,44
	2	11,11	11,11	11,11	11,11	
10	1	9,52	9,09	8,70	9,10	8,84
	2	8,33	9,09	8,33	8,59	
11	1	10,00	10,00	10,53	10,18	10,19
	2	9,52	10,00	11,11	10,21	
12	1	11,76	11,76	12,50	12,01	12,67
	2	13,33	13,33	13,33	13,33	

Table 5. Mean and SD of the push-down method.

	Mean	SD
Mean	10,71	1,97
Moment 1	10,42	1,91
Moment 2	11,01	2,35

By means of the Shapiro-Wilk test, we obtained that all data were normally distributed ($p > 0.05$) and consequently, a parametric test (paired sample t test) was used to determine whether there were statistically significant differences between the values provided by both methods.

The paired *t*-test of the first session versus the second one of the push-up ($t(11) = -2.245$, $p<0.05$) showed that there was a statistically significant difference between both examinations what means that the repeatability of the test is not as good as expected.

On the other hand, the paired *t*-test of the first session versus the second one of the push-down (t (11) =-1,199 p>0.05) showed that there was not a statistically significant difference between both examinations what means that the repeatability of the test is valid.

Due to the means of the two methods and the direction of the *t*-value in both cases, we can conclude that there was a statistically significant improvement in amplitude of accommodation performing the push-up method.

Regarding to precision, within-subject standard deviation (SDws):

$$SD_{WS} = \sqrt{\frac{\sum[(x_{i1} - x_{i2})^2]}{2n}}$$

Table 6. Push-up Within-subject SD.

Push-up1(x_{i1})	**Push-up2(x_{i2})**	**$x_{i1} - x_{i2}$**
8,33	10,17	-1.84
10,91	11,54	-0.63
13,33	14,63	-1.3
8,57	8,45	0.12
9,52	9,68	-0.16
11,11	13,04	-1.93
12,77	11,76	1.01
9,09	9,68	-0.59
10,71	12,24	-1.53
9,68	8,57	1.11
10,71	11,32	-0.61
10,53	12,77	-2.24
		SDws
		1.75

Table 7. Push-down Within-subject SD.

Push-down 1(x_{i1})	Push-down 2(x_{i2})	$x_{i1} - x_{i2}$
8,11	8.47	-0.36
9,93	9.1	0.83
13,97	15.02	-1.05
8,22	9.54	-1.32
8,33	10.8	-2.47
11,13	15.38	-4.25
12,78	10.53	2.25
9,54	10	-0.46
11,76	11.11	0.65
9,1	8.59	0.51
10,18	10.21	-0.03
12,01	13.33	-1.32
		SDws
		1.43

The results of the precision measured with the within-subject standard deviation show that the variation mean in every subject of the study is less than 0.25D which would be clinically significant.

The results generally show that the methods are clinically valid and have no systematic errors. That can be guaranteed because of the coefficient of Repeatability =2.77·SDws; in this case CR= 2.77·0.22=0.61.

As it is expected for a good agreement, all the mean differences that are obtained are very close to zero. The biggest mean difference in absolute terms (expressed in diopters) is found in push-up method. However, it can be seen that this mean difference is not clinically significant in terms of sphere (diopters) since it is below 0,75D, which is usually the limit of significance in clinical terms related to accommodation (10).

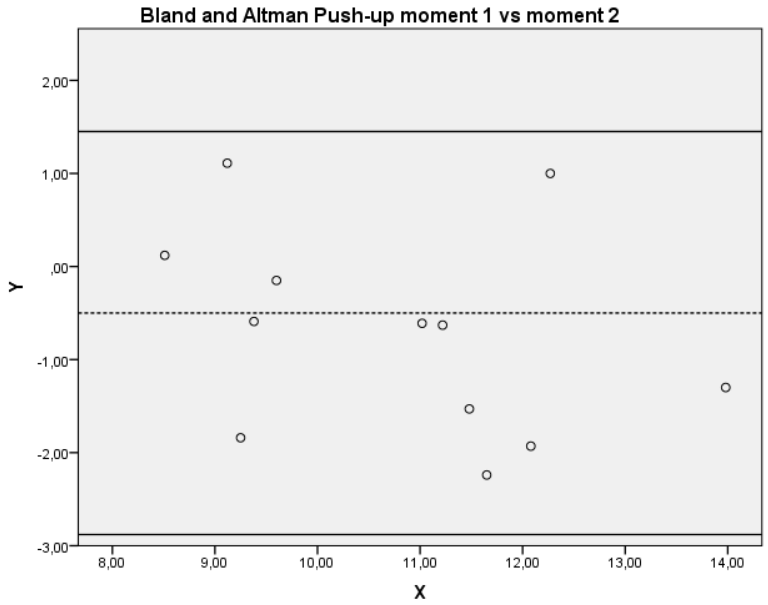

Figure 2. Bland and Altman plots showing the mean of the differences (mean) and the corresponding 95% limits of agreement (LoA) between the values provided by session 1 and 2 of the push-up method. X corresponds to the mean value of moment 1 and moment 2, Y is the difference between moment 1 and moment 2 (1-2).

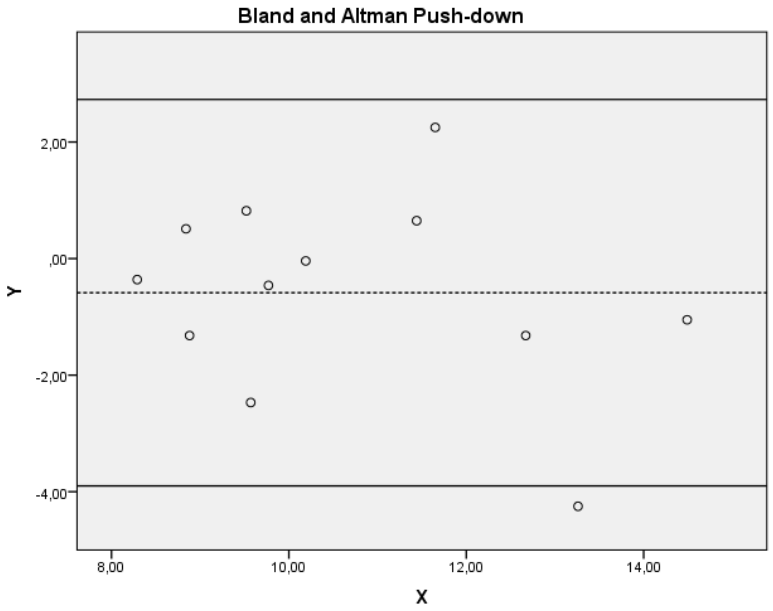

Figure 3. Bland and Altman plots showing the mean of the differences (mean) and the corresponding 95% limits of agreement (LoA) between the values provided by session 1 and 2 of the push-down method. X corresponds to the mean value of moment 1 and moment 2, Y is the difference between moment 1 and moment 2 (1-2).

DISCUSSION.

Many clinicians have observed that patients show the highest accommodative amplitudes with the push-up method (11).This method is faster to perform than some other techniques related to amplitude of accommodation, and therefore, more widely used. This study validates and quantifies the difference between the push-up and push-down methods, but also validates the repeatability of each technique.

The results of this study showed that the push-up method results had apparently higher accommodative amplitude [Table 2], compared to the push-down method [Table 4]. It should have been expected due to the fact that it is easier to report when the vision is clear after having it blurred than backwards and as a matter of that, the distance gets closer and the value of accommodation amplitude increase.

The fact that the result of the average AA in this study was around 11D and the average age of the patients was around 25 years old (even though according to table 1 the AA at age 25 should be 8.5D) should be explained because of the patients are in surroundings that imply to accommodate during great part of the day. Consequently, the subjects have acquired higher amplitude of accommodation.

The difference between the methods is predictable according to the type of accommodative system stimulation. In the push-up method, corresponding to the decrease in the target distance, the angular size of the retinal image increases and also the proximal stimulation to the accommodation increases, inversely proportional to the target distance (11).

Comparing of different methods using the Bland-Altman technique showed a good agreement between the push-up and the push-down methods. This finding was in agreement with the results of many other studies.

CONCLUSIONS.

The time and ease assessment of the accommodative amplitude, using the push-up and the push-down methods is the main advantage of performing these clinical methods. Especially, in the absence of a phoropter, the almost perfect agreement between these two methods can further emphasize their use as a routine procedure in the clinic, especially if a combination of the two techniques. Finally, the results obtained from the push-up method are very similar to the push-down results. As a matter of that, the end point of this study would be that both methods have similar results and would not make clinically significant differences.

ETHICAL AND SOCIAL COMMITMENT.

As its regulation indicates, the final project must have a section that refers to the transversal competence of ethical and social commitment. As a matter of that, at this point, the project will be analysed from an ethical point of view. Social and law implications to the research will be carefully studied too.

Firstly, it is necessary to emphasize the fact that the main purpose on this project is to study the repeatability of the push-up and push-down methods in the measure of accommodation amplitude. Research and knowledge in the field of optometry have a direct effect on the improvement of population's visual healthcare and as a result in their quality of life. The main purpose of the study and beneficence (one of the four basic principles of bioethics) are directly related.

About legal aspects, it is essential to keep two aspects in mind. First, it has been considered unnecessary that the twelve patients who participated in this study signed an informed consent about the clinical exams due to the fact that all of them were aware of the course of the research. Besides this, during the clinical execution the examiner safeguards the patients. Dangerous devices have not been used under any circumstances in this research study.

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