Journal of Sports Medicine & Doping Studies

Ruiz-Bailen et al., J Sports Med Doping Stud 2017,7:1
DOI: 10.4172/2161-0673.1000186

Research Article OMICS International

Left Ventricular Function Improve After Bench Press: A Speckle Tracking and 3D Echocardiography Study

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Received date: October 13, 2016; **Accepted date:** October 23, 2016; **Published date:** October 31, 2016

Abstract

Background: The speckle tracking echocardiography is a powerful tool that is expanding knowledge on cardiovascular physiology. At present fitness is an increasing sport, and the bench press is a typical exercise. The aim of this study was to investigate by speckle tracking echocardiography the systolic and diastolic properties of the left ventricle during bench press.

Methods: Interventional study. We perform an echocardiogram before, during and immediately after a bench press. During the bench press we assessed the changes suffered in systolic and diastolic functions. Speckle tracking parameter and 3D volume were calculated for left ventricle.

Results: In the study were included 59 male athletes with mean age 34.28 ± 9.54 years. Left ventricle ejection fraction is increased by 2D and 3D echocardiography [0.58 ± 0.07 versus 0.62 ± 0.07, p=0.017.] The strain, strain rate, and systolic and diastolic velocities of longitudinal left ventricular fibers (by Speckle Tracking) are higher during exercise [(Strain -21.1 ± 4.09 versus -27.28 ± 3.73, p<0.01) (Strain Rate -1.48 ± 0,30 versus -2.30 ± 0.57; p<0.0001]. The E/E' ratio was unchanged but improved diastolic function improve by Speckle Tracking echocardiography. After the exercise there was more left intraventricular synchrony. Strength training degree could be associated with compliance and synchrony of left ventricle.

Conclusion: During bench press a discrete increase in ejection fraction and large variations in myocardial deformation occurs. Diastolic function is unchanged by 2D echocardiography. Strength training degree could be associated with compliance and synchrony of left ventricle.

Keywords: Speckle tracking; 3D echocardiography; Athlete; Bench press

Abbreviations

S: Strain; SR: Strain Rate; LVEF: Left Ventricular Ejection Fraction; EDLVV: End Diastolic Left Ventricular Volume; ESLVV: End Systolic Left Ventricular Volume; VTI: Velocity Time Integral; SRS: Systolic Strain Rate; 2D: Two Dimensional; 3D: Four Dimensional; DTI: Doppler Tissue Imaging; RM: Repetition Maximal; IPAQ: International Physical Activity Questionnaires; ESC: European Society of Cardiology; PCWP: Pulmonary Capilar Wedge Pressure; VP: Mitral Flow Velocities Propagation; ASE: American Society of Echocardiography

Introduction

Speckle tracking echocardiography is introducing new hypotheses about the pathophysiology of cardiovascular elite athlete. The Speckle Tracking allows us to evaluate the strain (S), the strain rate (SR), tissue velocities and displacement; being it less influenced by the angle of study, or by the load nor sex, nor they age or systolic blood pressure values [1,2]. Ventricular remodeling that athlete produce is very variable, depending on the type of sport, age, gender, time or type of training, race or genetics [3]. We consider that there are two types of remodeled, concentric and eccentric.

Probably the most important remodeling was a mixture of both being generated by the adaptation of the myocardial cells. There may be a relationship between training degrees with myocardial performance. In a healthy person is assumed that in an exercise which is trained systolic and diastolic function be improved, increasing ejection fraction and left ventricular compliance. This could lead to an increase in Strain, Strain rate, peak systolic and diastolic velocities and displacement of left ventricular fibers [3].

Usually, studies are performed on elite athletes having completed the exercise. The fitness is a growing sport, and bench press exercise is very representative. However there are few studies on no elite, and is not known the immediate performance of muscle fibers during exercise, especially while strength training by bench press. With this study we evaluate the peak speeds, S, SR and displacement of left ventricular longitudinal muscle fibers in the bench press exercise. We also want to assess whether there is any relationship between degrees of strength training with echocardiographic parameters of myocardial performance.

Methods

Study Design

It is a cross-sectional study, where measurements were carried out before, during and immediately after exercise. Study was carried in gym "Emotion Sport Club of Jaén - http://emotionsportsclub.com/-" It belongs to PAIDI CTS 606 Andalusian Health Service Project No. PI-0585-2012, approved by the local ethics committee, and funded by the department of Health of the Government of Andalusia, Government Andalusia, Spain.

Inclusion phase was conducted during the last week of July 2013. We included male athletes between 25 and 40 years. We define athletes that: have a high level of physical activity (quantitative value>3000 meets / min per week) in international Physical Activity Questionnaires (IPAQ) (Spanish version 2002).

Exclusion criteria

- Athletes were excluded with any known cardiovascular disease or detected during the study
- Athletes with poor sound quality
- Athletes who do not wish to be included in the study, and therefore did not sign the Informed Consent
- Previous arrhythmias diagnosis
- Previous hypertension diagnosis

Intervention and clinical cohort

All patients meeting inclusion criteria were performed transthoracic echocardiography being recorded in high quality digital format (using acoustic catches) for further analysis "off line by Syngo software program. U.S. Siemens 2013®. Echocardiographic data were evaluated blindly (time and type of athlete will be unknown). Similarly were conducted three separate studies and will be assessed the degree of inter observer agreement.

Image acquisition and processing

Standard transthoracic echocardiograms were performed using a commercially available system (SC2000, Siemens®. U.S.). Transthoracic examinations were carried in the decubitus supine position. For the acquisition of left ventricular functional data was used the apical four-chamber orientation. Region of interest were manually traced along the endomyocardial border in the six segments. We adopted a six segments model to assess regional and global left ventricular performance in the longitudinal direction. The frame rate were as high as possible (70-120 f/s), with multiple focal point. All images were optimized with gain, compression, and dynamic range images. We use the probes 4V1C, and 4Z1c. Off-line analysis was performed blinded by Syngo software, U.S. Siemens®. 2013. We evaluated the usual echocardiographic parameters of American Society of Echocardiography. We calculate left ventricular ejection fraction (LVEF) by 2D and 3D volume, quantification of the E/E', estimating the PCWP and parameters derived from speckle tracking, such as S, SR, displacement, longitudinal and radial velocities in left ventricle.

Exercise stress-echo

It is a cross-sectional study, in which the measurements were carried out before, during and after exercise. Degree of strength training will be assessed by the maximum load for 1RM. The following protocol was used to evaluate the strength and prevent injuries:

- Start with a warm-up set with a light load allowing you to perform 10 repetitions
- Rest for one minute
- Perform another series with a resistance heating that will allow complete 3-5 repetitions. This usually means increased 5-10% of the previous set
- Rest for two minutes
- Estimate another increase (5-10%) that allowed you to fully 2 or 3 repetitions
- Rest for four minutes
- Estimate another increase (5-10%) that allows for a single repetition of the exercise
- Break four minutes and then calculate a new moderate increase in weight (5-10%), and repeat the test
- If you cannot lift the weight, after the break four minutes, the weight (2.5 to 5%) will be reduced, and then repeat

Continue increasing or decreasing the weight as necessary to determine their repetition maximum (RM) real. After determining the training load using the 1 RM test, the load can move a total of 10 replicates were estimated. Training protocol is based on the 10 sets of 10 repetitions with a load current of 75% of 1 RM estimating, each with a break of 1'30 "between sets, during the conduct of the exercise, series and rest included, perform echocardiography [4].

Statistical Analysis

A study for quantitative variables was performed using ANOVA. For variables that did not follow a normal probability distribution was used the means test for nonparametric samples. Their results were presented using means and standard deviations. It was regarded a p value <0.05 statistically significant. The correlation between LVEF 2D and 3D were evaluated using the Spearman test and linear regression. Were also conducted bivariate correlations enters the weight of the 1 RM with echocardiographic parameters using the Spearman test. We were used correlations between variables by Pearson's r coefficient for variability intra observer.

Results

63 male Caucasian athletes were included in the study; one was excluded for developing atrial tachycardia diagnosed disease Wolff-Parkinson-White. Mean age were 34.28 ± 9.54 years. RM values were: mean 97.51 Kg; median 100.6 ± 31.39 Kg. Intra observer basal variability was 0.861 for 2D-LVEF; 0.878 in S 0.861 for SR and 0.784 for systolic peak longitudinal velocity (all p<0.0001).

Left ventricular systolic function

After completing the exercise a discrete increase in LVEF was observed by volumetric 2 and 3D echocardiographs (Tables 1 and 2). Likewise, a higher volumetric increase is detected in the apical segments, apicolateral specially. The correlation coefficient between LVEF by 2 and 3D was 0.446 (Spearman), with p=0.028. By linear regression and an R2 of 0.733 and p=0.016 is observed. End-diastolic volumes increase very slightly, without modifying the sphericity index (0.6). The tissue Doppler image shows increase septal and lateral systolic velocities "s" of the mitral annulus.

Transmitral Flow			
	Basal	**After bench press**	**P-value**
Sphericity index	(n=35) 0.74 ± 0.14	(n=30) 0.84 ± 0.097	0.580
Peak velocity E wave (m/s)	(n=38) 0.86 ± 0.25	(n=36) 1.10 ± 0.21	0.000
Peak velocity A wave (m/s)	(n=37) 0.47 ± 0.15	(n=36) 0.78 ± 0.18	0.000
E deceleration time (ms)	(n=37) 204 ± 54	(n=35) 205 ± 56	0.849
IVRT (ms)	(n=37) 86.3 ± 19.5	(n=35) 73.5 ± 16.7	0.001
Transmitral VTI (m)	(n=37) 0.22 ± 0.043	(n=36) 0.23 ± 0.051	0.301
Tei Index	(n=31) 0.38 ± 0.13	(n=32) 0.33 ± 0.11	0.62

Table 1: Diastolic basal to after bench press parameters.

Mitral Tisular Doppler Image			
(m/s)	**Basal**	**After bench press**	**P-value**
E´septal	(n=38) 0.14 ± 0.037	(n=38) 0.19 ± 0.04	0.000
E´Lateral	(n=34) 0.21 ± 0.031	(n=38) 0.23 ± 0.04	0.000
S septal	(n=37) 0.11 ± 0.03	(n=37) 0.16 ± 0.053	0.000
S Lateral	(n=34) 0.13 ± 0.03	(n=37) 0.23 ± 0.056	0.000
A´ septal	(n=36) 0.09 ±0.02	(n=37) 0.13 ± 0.05	0.000
A´ Lateral	(n=34) 0.09 ± 0.09	(n=36) 0.12 ± 0.047	0.559

Table 2: Mitral tisular doppler image.

Diastolic parameters

Table 3 shows diastolic parameters. Pulsed Doppler transmitral flow shows a discrete increment of the E wave velocity, whereas diminished duration of peak med-diastolic wave velocity. Also a clear increase in wave velocities E'septal and lateral occurs. However not change the E / E' ratio. Similarly no were significant changes in the VP or filling of the pulmonary veins. All this is consistent with the absence of modification of the PCWP.

Pulmonary Veins Filling flow			
	Basal	**After bench press**	**P-value**
Velocity S (m/s)	(n=45) 0.51 ± 0.16	(n=31) 0.56 ± 0.13	0.146
Velocity D (m/s)	(n=45) 0.56 ± 0.13	(n=31) 0.57 ± 0.19	0.780
S VTI	(n=31) 0.14 ± 0.072	(n=21) 0.14 ± 0.12	0.912
D VTI	(n=30) 0.16 ± 0.089	(n=21) 0.24 ± 0.23	0.104
Systolic fraction filling	(n=37) 0.49 ± 0.47	(n=31) 0.13 ± 0.7	0.748
Velocity AR	(n=28) 0.27 ± 0.078	(n=18) 0.46 ± 0.15	0.00
Deceleration D wave time	(n=30) 267.9 ± 113.7	(n=18) 236 ±76.4	0.298

Table 3: Pulmonary veins filling flow.

Speckle tracking parameters

Global Peaks systolic longitudinal velocities were increased and also they increased in all segments except the segment apicoseptal (the increase was not statistically significant) (Figures 1-4). Interestingly, the normalized heart rate delay of systolic peak velocities between basal and lateral segments was decreased which may suggest an improvement in ventricular synchrony. Early longitudinal diastolic velocity (E) was decreased during exercise), suggestive of increased left ventricular compliance. Left ventricular radial velocities were modified similarly to the longitudinal. S, SR and segmental left ventricular also suffered average systolic and diastolic increase (Tables 4 and 5) (Figures 5 and 6). Similarly, despite absence of changes in the E/E ', we observed changes in relationships S/SR, IVRT/SR and IVRT/SR ratio suggestive of improvement in left ventricular compliance during exercise. We have obtained a significant correlation between the maximum load weight of 1 RM with

- Septal wave E' velocity (correlation coefficient 0,247, p=0.010)
- Pulmonary vein systolic VTI (correlation coefficient 0.215, p=046)
- The delay of peak systolic velocities of longitudinal fibers (correlation coefficient -0.273; p=0.004)
- Mid-diastolic velocities of longitudinal fibers (correlation coefficient 0.193, p=.005)
- Radial velocities of the E and A waves (correlation coefficient 0.295, p=0.003 and 0.287, p=0.006 respectively)
- Mid-diastolic strain (correlation coefficient -0.255; p=0.010)
- Peak systolic SR delay (correlation coefficient - 476; p=0.0001)
- Longitudinal displacement (correlation coefficient 0.278; p=0.038)
- Longitudinal displacement delay time (correlation coefficient 0.433; p=0.002)
- Longitudinal mid-diastolic displacement (correlation coefficient 0.398; p=0.004).

Left Ventricular Ejection Fraction			
	Basal	Press bench	P- value
LVEDV (mL) 3D	(n=33) 117 ± 28.4	(n=33) 113 ± 26	0.284
LVESV 3D (mL)	(n=33) 54.2 ± 18.66	(n=33) 41 ± 14.7	0.017
MAPSE	(n=56) 19.17 ± 3.93	(n=47) 21.29 ± 3.67	0.006
LVEF 3D	(n=51) 0.58 ± 0.07	(n=52) 0.62 ± 0.07	0.017
LVEF 2D	(n=56) 0.57 ± 0.77	(n=49) 0.63 ± 0.78	0.000

Table 4: Left ventricular ejection fraction.

Speckle Tracking			
	Basal	Press bench	P-value
Peak systolic longitudinal velocity (cm/s)	(n=36) 4.29 ± 1.10	(n=31) 6.10 ± 2.19	0.000
LV longitudinal velocity delay (anterior-lateral walls) ms	(n=36) 122.33 ± 52.92	(n=28) 78.5 ± 64.79	0.055
LV longitudinal radial velocity	(n=36) 2.70 ± 0.98	(n=31) 3.79 ± 1.54	0.000
LV longitudinal radial delay (ms)	(n=35) 125 ± 48.35	(n=27) 118 ± 44.58	0.412
LV longitudinal Strain	(n=36) -21.1 ± 4.09	(n=31) -27.28 ± 3.73	0.000
LV longitudinal Strain delay (ms)	(n=35) 109 ± 76.03	(n=28) 93.5 ± 63.16	0.506
LV longitudinal Strain E	(n=3) -19.28 ± 2.34	(n=1) -25 ± 1.37	0.001
LV Strain Rate	(n=36) -1.48 ± 0.30	(n=31) -2.30 ± 0.57	0.000
LV Strain Rate E	(n=33) 1.21 ± 0.48	(n=27) 1.83 ± 0.77	0.016
LV Strain Rate A	(n=33) 0.47 ± 0.34	(n=27) 0.67 ± 0.95	0.191
S/Strain rate	(n=39) 13.2 ± 3.29	(n=35) 11.6 ±1.95	0.000
IVRT/ SR	(n=54) -64.43 ± 17.48	(n=47) -33.51 ± 10.46	0.000

Table 5: Speckle tracking.

Discussion

Sport provides clear benefits. Elite athletes could have higher tissue velocities and strain. But most athletes are not elite athletes. On the other hand most studied sports are soccer, cycling, running, using young athletes. Despite increase in fitness there are no studies on the changes that occur during training on the longitudinal fibers while

Citation: Ruiz-Bailen M, Cobo-Molinos J, Espada-Fuentes JC, Castillo-Rivera AM, Martínez-Amat A, Martínez-Ramírez MJ, Pola-Gallego-de-Guzmán MD, Sánchez-Ramos S and Ramos-Cuadra JA (2017) Left Ventricular Function Improve After Bench Press: A Speckle Tracking and 3D Echocardiography Study. J Sports Med Doping Stud 7: 186. doi:10.4172/2161-0673.1000186

bench pressing is performed in amateur athletes. In the present study we found that there is a slight increase in LVEF obtained by 2 and 3D. However we have obtained a clear increase of velocities and deformity. This reflects a clear contractile improvement is not fully explained by the load, in fact we have not achieved significant changes in comprehensive speeds time of ventricular filling, or ventricular geometry. The increase of S and SR has been described in other sports [5,6] even without detecting changes in LVEF [7]. Although it is accepted that an increase of S and SR occurs during exercise in elite athletes today do not know the behavior of the myocardial fibers in the non-elite athletes [8-11].

Although we have not obtained changes in diastolic function, we found by Speckle Tracking signs suggestive of a possible improvement in diastolic function and a potential increase in left ventricular compliance. Acar et al. [12] obtained improved S in the left atrium. These findings may explain the lack of variability in the E/E 'and PCWP [13].

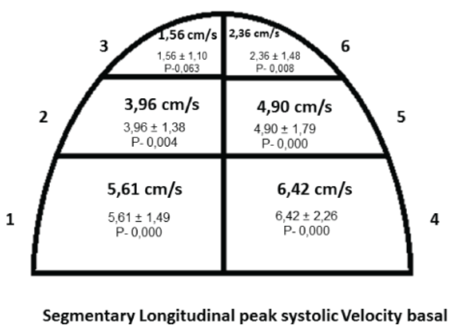

Figure 1: Segmentary longitudinal peak systolic velocity basal.

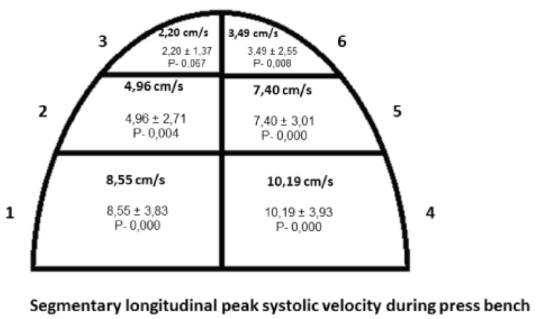

Figure 2: Segmentary longitudinal peak systolic velocity during press bench.

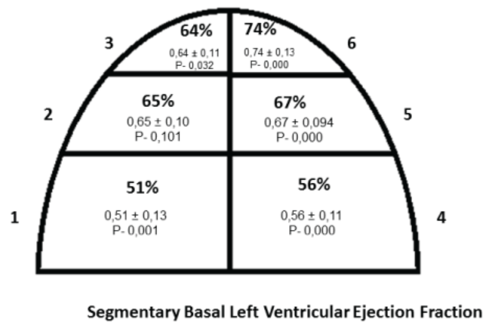

Figure 3: Segmentary basal left ventricular ejection fraction.

This could suggest that fitness may improve diastolic function in patients with heart disease. [13-15]. In preclinical studies is demonstrate that cardiovascular adaptations to exercise are dependent intensity and that could change the molecular architecture of the cardiomyocyte. Kemi et al. [16] demonstrated that cardiovascular adaptations to training are intensity-dependent. A close correlation between VO_2max, cardiomyocyte dimensions and contractile capacity suggests significantly higher benefit with high intensity, whereas endothelial function appears equivalent at moderate levels. Thus, exercise intensity emerges as important variable in future preclinical and clinical investigations. This group also detects that exercise training remodel the hearts [17].

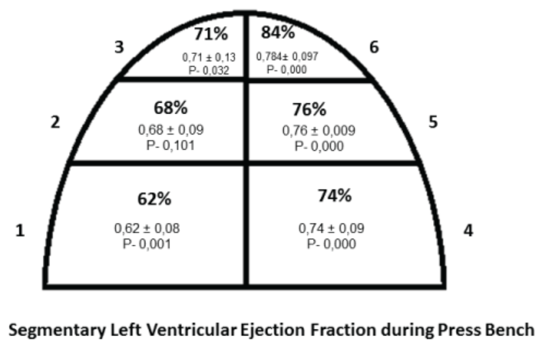

Figure 4: Segmentary left ventricular ejection fraction during press bench.

This would also have important clinical implications, could be assessed by cardiac imaging or changes in intra ventricular pressure. So actually there is no evidence that strength training using bench press modify contractility and left ventricular compliance. This study indicates that training degree beneficially can improve left ventricular compliance. This could explain the clinical improvement detected by high levels of muscular strength appear to protect hypertensive men and woman against all-cause mortality [18-21]. This study raises a new question we could exercise improve cardiac synchrony? This could also have an important clinical applicability implying an increased cardiac output.

Limitations

This is a pilot study with a low samples and only show possibility of practicing hypothesis. It was done in gym, and results should be confirmed. There may be variability in relation to age, and a possible bias related to sex, but the speckle tracking is independent sample of those situations. In any case we believe that this age could be closer to reality than those in young elite athletes.

Conclusion

During bench press to systolic and diastolic Increase discrete functions. Speckle tracking is more sensitive than the 2D detect changes in myocardial performance suffered. Intensity strength training might correlate with improved parameters of diastolic function.

Acknowledgements

I want to thank my Kendo and Iaido "Juan Antonio Coronil Moreno" Sensei all his contribution so that I regained my confidence in myself. I also wish to sincerely thank Mr. Urbano Ríos and Pablo Puertas, for making possible the realization of this study. Similarly Siemens U.S and Spain® want to thank them for leaving free echocardiography equipment high-end gym. And finally the Emotiont's Club Jaén and its users for allowing use of their facilities and their users paid to it.

Funding

Servicio Andaluz de Salud. SAS Project nº PI-0585-2012. Approved by the local ethics committee, and funded by the "Consejería de Salud" of the Government of Andalusia. Spain. PAIDI CTS-606.

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