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ORIGINAL ARTICLE
EXERCISE AND SPORT CARDIOLOGY

# Home-based exercise program improves normal right ventricle function in renal transplant recipients

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## ABSTRACT

BACKGROUND: Right ventricular function is strongly associated with clinical outcomes in populations at high cardiovascular risk. Renal Transplant Recipients have multiple coexisting comorbidities potentially involved in the biventricular dysfunction including the right ventricular chamber. Speckle tracking echocardiography is recently used to investigate the normal function of this chamber. The study aims to verify whether global longitudinal strain carries clinical and prognosis implications in the renal transplant recipients during 1 year of regular unsupervised physical activity and compared to a control group.
METHODS: A group of 50 transplant recipients, aged 49.6±11.5 was submitted for 1 year to a moderate intensity of mixed exercise. All the subjects were followed by echocardiographic exam every 6 months, only 25 subjects with a high quality of image were investigated by 2D Speckle tracking strain analysis with the measurement calculated at T0, T6, and T12 months.
RESULTS: Renal transplant recipients started with low values of right ventricle global longitudinal strain compared to health controls; it increased significantly (P<0.01) after 12 months of exercise, restoring the normal range.
CONCLUSIONS: Moderate intensity of physical exercise, despite unsupervised, support a normal RV ventricular performance in renal transplant recipients' strain analysis contribute to plan a correct follow-up, with prognostic impact in these patients practicing physical exercise.

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KEY WORDS: Kidney transplantation; Physical examination; Exercise; Heart ventricles; Echocardiography.

Renal transplant recipients (RTR) patients are at high risk for cardiac dysfunction as consequence of existing comorbidities such as diabetes, hypertension, and sedentary behavior.[1] The cardiovascular (CV) mortality risk increased after surgical treatment due to multiple drug therapies, immunosuppression and reduced physical activity.[2, 3] Recently, a tailored physical exercise regimen at moderate intensity, conducted in supervised way[4, 5] has been proposed in these subjects, to contrast the multiple CV risk's factors. Despite an inadequate left ventricle (LV) cardiovascular performance has been demonstrated[6] to play a role for regular physical activity, otherwise, the Right Ventricle (RV) performance is fundamental for its peculiar contribution to the physiological myocardial function. Multiple information has been reported on RV function in several conditions and pathologies.[7, 8] In addition to the standard echocardiographic parameters, Strain analysis by speckle tracking (STE) method is considered a useful non-invasive index to assess myocardial contractility.[9, 10] However, no data is available for the clinical application of RV chamber strain in case of subjects at high CV risk following unsupervised physical exercise program. The study aims to verify the eventual changes of the RV strain in a group of RTR trained for at least 12 months with mixed exercise at moderate intensity practiced in in outdoor context. Results have been matched with a control group of healthy control subjects (HC) following the same program.

## Materials and methods

Fifty RTR were enrolled for a prospective observational study from 2016 to 2020. All the subjects were evaluated at the Sport and Exercise Medicine Center in University of Florence with anamnestic questionnaire, physical examination, ergometric test and echocardiographic evaluation with speckle-tracking analysis. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. From a group of 50 RTR patients enrolled for a prescription program of training with mixed exercise for at least 12 months, only 25 subjects, aged 49±11.5 (13 males and 12 females, time to transplant 8.8±7 years) with a complete follow-up and a high quality of echo images were considered for the protocol and investigated for the specific Echocardiographic 2D and strain study. The subjects were recruited within the period of 2 years from 2016 to 2018. Subjects affected by acute coronary events, arrhythmias, atrial fibrillation, or tachi-dysrhythmias in the previous 3 months were previously excluded from the study, as well as individuals with uncontrolled diabetes or hypertension. Most of the RTR's (58%) had mild or moderate arterial hypertension and were under antihypertensive therapy (calcium channel blockers, alpha blockers, ACE inhibitors or ARBs). Blood pressure was generally well controlled by therapy. Immunosuppressive therapy for RTR's included a calcineurin inhibitor (cyclosporine or tacrolimus) in combination with mycophenolate or everolimus and steroids (methylprednisolone). In order to correctly establish the range of the exercise intensity, the investigation was completed by an ergometric test conducted up to the 75% of the maximal effort using cycle ergometer (Ergoline 200 GmbH-Esaote, Bitz, Germany). It consisted in modified Bruce protocol with progressive load increase of 25 W every 2 min and blood pressure (BP), heart rate (HR), and rating of perceived exertion (CR-10) recording.[11] The exercise program included both aerobic (walking, cycling or light jogging) and strength (mixed physical activity, *e.g.,* light weightlifting, counter resistance exercises involving at least 8 muscles groups) training performed for 5 to 6 days/week for at least 30 to 45 minutes each session. The training intensity was established following the American College of Sports Medicine recommendations (ACSM).[12] The participants were addressed to keep heart rate in the range of moderate intensity calculated by Karvonen formula[13] during the diagnostic setting. The physical activity was conducted in an unsupervised way. All the subjects were invited to maintain a constant adhesion to the program, and self-reported through a daily questionnaire or a mobile phone application the physical activity performed. The echocardiographic exams were performed by two experts certified cardiologists. The exams were performed by MylabSeven-ESAOTE echocardiography using the 4MHz probe equipped with a multifrequency phased array probe (SP2430, 1-4 MHz) for adult cardiology. For the intra-observer variability, the echo recordings were re-analyzed after 3 days of the first acquisition and de-novo recalculated by two independent observers and within a 3-week period by one observer. Standard measurements of the LV were made in accordance with American Society of Echocardiography (ASE) guidelines.[14] LV linear dimensions (LVDd) were measured from a parasternal long axis orientation and LV mass were calculated using the ASE corrected equation. In order to provide a comprehensive assessment of LV wall thickness, at least 3 measurements were made from a parasternal short axis orientation at basal and mid-levels from the antero-septum, infero-septum, posterior wall, and lateral wall. Mean wall thickness (MWT) was calculated as an average of all the segments and the maximum value (MaxWT)was also reported. LV end diastolic volume (LVEDV), LV end systolic volume (LVESV) and ejection fraction (EF) were calculated from a Simpson's biplane method using both apical four and two chamber orientations. An indication of LV geometry and relative wall thickness was determined by the dividing LVEDV into LV mass (LV mass/LVEDV). Standard 2-dimensional measurements of the RV chamber were also made in accordance with ASE guidelines.[15] All the data were indexed to the body surface area (BSA). The RV linear dimensions outflow tract (RVOT) was measured, from parasternal long axis (RVOTplax) and the RV fractional area change (RVFAC) was calculated as differences between diastolic area (RVDa) and systolic area (RVSa) obtained from the modified apical four chamber orientation window. The systolic RV function was also investigated by TAPSE (Tricuspid annular plane systolic excursion) measure. Diastolic function of RV was also evaluated by the measurement of E/A ratio and TDI measure of the RV free wall. Images for offline assessment of myocardial deformation were acquired from the standard examination using a focused apical 4-chamber view for the LV


Figure 1.—Example of post processing strain analysis of RV chamber by XStrain software. The lines reproduce the strain value per each segment of the RV chamber. Starting from the apical 4-chamber view for the LV, it has been modified lateral, for the RV.

and a modified lateral, apical4-chamber view for the RV (Figure 1).[10, 16] In both views frame rates were adjusted to between 40 and 90 frames per second (FPS). During the offline analysis (ESAOTE XStrain software) a region of interest was placed around the LV from basal septum through to the basal lateral wall ensuring the whole of the myocardium was encompassed within. This provided six myocardial segments and an average of these provided a global index of LV longitudinal ε. For the RV the Offline analysis involved placing the region of interest around the RV lateral wall only from base to apex. The strain parameters considered, were of both left and right ventricles. They were the Global Longitudinal Strain (GLS) value, obtained from the analysis of all the myocardial segments, and Med GLS, as expression of mean averaged strain values from 3 cardiac cycles (Figure 1). Despite the state of art[17] supports the importance of the FW (free wall) strain for the RV chamber and in order to evaluate the global contribution of both the ventricles during the myocardial contraction, the value of Med GLS, as expression of mean averaged strain values of all the RV and LV myocardial segments have been reported.

Table I.—*RV systo-diastolic function and strain analysis in RTR and HC.*

| | T0 | | | T6 | | T12 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | RTR | HC | P | RTR | HC | P | RTR | HC | p |
| RV | 23.46±1.2*# | 22.09±1.3* | 0.031 | 22.09±1.2*# | 21.64±1.7* | 0.016 | 22.86±0.8*# | 21.77±1.4* | 0.02 |
| TAPSE | 22.07±2.4 | 21.99±2.4^ | 0.027 | 22.48±3.1 | 21.0±2.36^ | NS | 23.72±3.1 | 21.50±2.6^ | NS |
| RVFAC | 40.48±8.2 | 51.05±5.9 | NS | 41.52±6.7 | 51.63±6.8 | NS | 42.66±6.9 | 52.53±5.8 | NS |
| PPr | 19.84±3.45 | 18.6±4.78 | NS | 18.8±3.81 | 18.7±5.09 | NS | 18.32±3.41 | 17.9±3.90 | NS |
| E(RV) | 54.61±10.97 | 52.32±10 | NS | 51.2±10.48 | 52.0±10 | NS | 54.63±8.87 | 51.91±10 | NS |
| A(RV) | 41.45±9.35 | 34.05±6.8 | NS | 49±8.79 | 33.32±6.4 | NS | 43.86±5.86 | 33.95±6.9 | NS |
| RVGLS | -24.43±6.31 | -24.8±4.0^ | 0.006 | -23.37±4.7 | -26.96±4.2^ | 0.007 | -24.5±5.58 | -27.59±3.4^ | 0.01 |
| RVMedGLS | -23.11±5.9 | -25.28±3.8^ | 0.013 | -22.88±4.4 | -26.69±4.0^ | 0.002 | -24.6±6.4 | -27.52±1.4^ | 0.01 |

RV: right ventricle; TAPSE: tricuspid annular plane excursion; RVFAC: right ventricle fractional area change; PPr: pulmonary pression; RVGLS: right ventricle global longitudinal strain; RV Med GLS: right ventricle medium global longitudinal strain.
*Significance between subject factors; §significance within subject factors; #significance within RTR group; ^significance within HC group

### Statistical analysis

All data are expressed as mean and SD. Comparisons within and between groups over time were analyzed by mixed model repeated measures analysis of variance (RM ANOVA), Mauchly's test of sphericity and Levene's Test for equality of variances were used to exclude any possible violation of ANOVA assumptions. "Time" (variable values at baseline and at each follow-up) and "group" (RTR-HC) were considered as within-subjects and between-subjects factors, with three "time" and two "group" levels, respectively, interaction time*group was also checked. All statistical analysis was performed by using IBM-SPSS® version 26.0 (IBM Corp., Armonk, NY, USA). In all analyses, a two-sided P value <0.05 was considered statistically significant.

## Results

All data were within the normal range for both the groups during the time of observation, when all the subjects reported to be adeherent to the Home-based exercise program prescribed. Despite the study has been dedicated to the RV chamber study, however the data reported include all the myocardial function parameters, in order to avoid or to miss some important data of the interdependence relationship of the two ventricles. The analysis shows that most parameters, including EF, showed some small improvement after the exercise intervention despite with varying significance (Supplementary Digital Material 1: Supplementary Table I). Differently, the LV GLS shows a significant increase (P<0.0001), especially within the groups over time and particularly in RTR, in whom the baseline strain values started from a lower level. The same trend has been observed for the RVGLS parameter. RV chamber maintains normal diameter, without any significant modification during the 12 months of exercise. Regarding the diastolic pattern, a normal profile was observed in all the subjects investigated (Supplementary Table I). Supplementary Digital Material 2 (Supplementary Table II) and Table I show separate data for the two groups analyzed and their modifications during the follow-up period. Considering the data of the groups separately, the analysis of the single group investigated has shown a significant increase of the EF value within both groups (P=0.001), especially if observed during time (P=0.007 in HC and P=0.008 in the cases) of the study. Particularly the GLS of the LV chamber resulted to be significantly improved in both groups, with maximum value after 6 months. This behavior is more evident in HC if compared to RTR. Regarding the RV function only in HC a significant increase of the strain value of RVGLS (P=0.006); mean RV strain P=0.013)has been observed. The longitudinal RV function (TAPSE) demonstrates a significant variation in HC (P=0.027) (Table I). In RTR, the RV performance maintains normal as demonstrated by strain values (RV GLS and Med RV GLS) and TAPSE value (Table I).

## Discussion

RTR is a peculiar population of subjects at high CV risk, nevertheless progressively involved into the mixed exercise programs at moderate intensity. This is normally allowed after a specific clinical and cardiological instrumental evaluation.[5] The effects of regular physical exercise in RTR have been studied in first line for the LV chamber.[6] This approach is resulted particularly important to give the clinical information, to allowing and to panning the intensity of the exercise program. On the contrary, no data have been reported on the RV chamber performance. The RV chamber, for long time neglected, has in fact progressively acquired an important role to understand information on the changeable loading condition and factors. It has a peculiar anatomical structure, which represents the main difficulty to approach its study. More recently, it has been demonstrated that, in addition to the standard echocardiographic parameters, the RV strain analysis can detect an eventual worse prognosis in numerous diseases, like chronic kidney disease (CKD). The present investigation is, to our knowledge, the first study among post-transplant renal subjects submitted to a long term home-based physical exercise program where the RV chamber contribution is considered to consolidate the knowledge of the impact of physical exercise. This study, despite it is a pilot study, supports, in first line, the feasibility of the RVGLS-4C strain evaluation in RTR. The RV strain parameter seems to be useful to complete the assessment of the physiological mechanisms of regular physical exercise and to contribute to confirming its positive effect. Considering the two ventricular chambers normally working together and in an inter-dependent way, the observation of a normal function of the RV for all the duration of the program is relevant and not verified before. Pulmonary pressure values were moreover normal for all the time of observation. Particularly, in case of post-transplant subjects in whom the cardiovascular profile can be influenced by a potential cardiotoxicity due to the multiple drugs therapy and prolonged sedentarism, the periodical follow-up of the global myocardial function seems to be strongly suggested, especially in case of a long-term follow-up. This is more relevant if the potential pro arrhythmic effect of the exercise, even if practiced at moderate intensity, needs to be excluded as in these subjects. The myocardial profile of the present investigation has included also the diastolic function of the two chambers and pulmonary pressures, which all resulted normal. In addition, the RV strain data obtained agree with data previously reported in literature in a pre-/postphase of surgical treatment of RTR.[16] Literature reports in fact that, after surgical treatment, the RV strain comes back to a normal range. From the present study the RV strain does not modify substantially if compared to HC. This behavior highlights the importance of this parameter and supports the role to follow-up the effects of the exercise program. In any case, the absence of significant modifications could be referred to a moderate level of the physical activity prescribed and as consequence of the fact that RV is a low gradient pressure chamber and therefore poorly affected by acute modifications. The improvement of the function of both the ventricles in RTR is evident after 6 months of exercise, with a decrease of the performance after that period. In HC this goal is reached after 12 months of exercise. This difference could be attributed to better RV condition at the onset of the study in HC. To confirm this hypothesis, the RV chamber shows in fact a progressive reduction of the diameters and maintaining the FE (RVAC) normal values in both the groups. If the investigation is referred to a larger field of interest, potentially related to the importance to maintain the normal organ function after the transplantation, the present study highlights the relevance to address the RTR to an individualized exercise prescription program. This should include also a strict and regular echocardiographic follow-up in the subjects involved, especially if they undergo to unsupervised program. A complete evaluation of the heart's function by a periodical and complete echo exam is therefore fundamental especially in case of a specific exercise program. Particularly for RV strain, this evaluation, could be largely proposed, as noninvasive and routine estimation of myocardial risk's stratification in RTR, to contribute to predicting the survival after renal transplantation.

### Limitations of the study

Regarding the modality to guarantee a correct follow-up of the subjects, a six-months period has been accepted as a good timing, as previously tested in the same kind of subjects.[18] It has not been yet clarified the eventual impact of the time from transplant on the results obtained. The population investigated has in fact a wide interval of time to transplantation. This could be considered as one of the principal limitations of the study. In fact, the data obtained need to be evaluated in a larger context specially to detect the eventual best time to give indications to start with the exercise's intervention.

## Conclusions

In any case, the preliminary data obtained confirm the positive role of the moderate exercise on the RV chamber, as independent factor. This observation could support the interest of scientific sounders in implementing the actual general recommendations for exercise prescription in transplant recipients toward specific guidelines in order to specify the different level of the intensity of the exercise.

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*Conflicts of interest.*—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

*Authors' contributions.*—Melissa Orlandi, Beatrice Leone and Elena Zappelli have given substantial contributions to study collection and data analysis; Laura Stefani and Gianni Pedrizzetti contributed to study conception and design; Laura Stefani contributed to the study supervision; Vittorio Bini contributed to the performance of the statistical analysis; Melissa Orlandi and Laura Stefani contributed to the manuscript draft. All authors read and approved the final version of the manuscript.

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SUPPLEMEMENTARY DIGITAL MATERIAL 1

Supplementary Table I.—General and echocardiographic parameters of HC and RTR.

| All | T0 | T6 | T12 | P values | T0 vs. T6 | T6 vs. T 12 | T0 vs. T12 |
|---|---|---|---|---|---|---|---|
| Age (yrs) | 48.24±10.12 | 49.06±10.56 | 49.04±10.47 | | Ns | Ns | Ns |
| Weight (kg) | 71.59±13.85 | 70.68±13.43 | 70.38±13.72 | | Ns | Ns | Ns |
| Height (cm) | 171.47±10.96 | 171.55±10.96 | 171.55±10.96 | | Ns | Ns | Ns |
| BMI (kg/m2) | 23.95±3.27 | 23.97±3.07 | 23.86±3.06 | | Ns | Ns | Ns |
| HR (bpm) | 70.71±10.49 | 69.14±9.55 | 68.92±8.22 | | Ns | Ns | Ns |
| EF (%) | 59.12±4.71 | 60.47±5.35* | 62.65±5.68* | | Ns | 0.05 | 0.001 |
| Aortic root (mm) | 32.31±3.33 | 31.86±3.06 | 32.24±3.08 | | Ns | Ns | Ns |
| LA (mm) | 36.45±3.88 | 36.35±3.95 | 37±4.19 | | Ns | Ns | Ns |
| IVS (mm) | 9.26±0.87 | 9.32±0.84 | 9.35±0.72 | | Ns | Ns | Ns |
| PW (mm) | 8.97±0.84 | 9.04±0.79 | 9.11±0.70 | | Ns | Ns | Ns |
| LVEDD (mm) | 48.25±3.86 | 48.64±3.56 | 49.1±3.49 | | Ns | Ns | Ns |
| LVESD (mm) | 29.08±3.64 | 28.86±3.85 | 29.2±3.48 | | Ns | Ns | Ns |
| RWT | 0.38±0.07 | 0.36±0.03 | 0.37±0.03 | | Ns | Ns | Ns |
| SR | -1.81±0.49 | -1.9±0.49 | -2.07±0.65 | | Ns | Ns | Ns |
| CMI (g/m$^2$) | 99.09±19.86 | 100.22±18.23 | 103.65±18.39 | | Ns | Ns | Ns |
| LV GLS | -18.42±2.83* | -19.7±2.73* | -20.99±3.27* | | 0.02 | 0.03 | <0.001 |
| LV med GLS | -18.79±3.14 | -19.41±2.61* | -20.67±2.52* | | Ns | 0.02 | 0.001 |
| E(mm/s) | 75.12±16.22 | 71.98±16.51 | 73.82±17.49 | | Ns | Ns | Ns |
| A(mm/s) | 59.04±19.44 | 59.53±17.28 | 63.45±16.62 | | Ns | Ns | Ns |
| E/A | 1.35±0.51 | 1.32±0.53 | 1.27±0.42 | | Ns | Ns | Ns |
| IVRT (ms) | 77.04±14.77 | 79.39±13.79 | 76.22±12.21 | | Ns | Ns | Ns |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| DT (ms) | 195.05±36.30 | 190.95±40.61 | 196.82±36.96 | | Ns | Ns | Ns |
| E1 | 9.89±2.92 | 10.21±2.41 | 10.55±2.59 | | Ns | Ns | Ns |
| A1 | 10.24±2.29 | 10.15±2.63 | 10.53±3.15 | | Ns | Ns | Ns |
| S | 7.78±1.38 | 8.06±2.03* | 9.04±2.84* | | Ns | 0.05 | 0.005 |
| MAV | 19.86±2.60 | 19.32±2.92 | 20.02±2.66 | | Ns | Ns | Ns |
| E/E1 | 7.65±2.30 | 7.13±2.13 | 7.17±2.58 | | Ns | Ns | Ns |
| RV (mm) | 22.83±1.34 | 22.3±1.61 | 22.39±1.27 | | Ns | Ns | Ns |
| TAPSE (mm) | 22±2.45 | 21.81±2.86 | 22.76±3.12 | | Ns | Ns | Ns |
| RVAC (%) | 44.23±9.01 | 45.11±8.11 | 46.02±8.04 | | Ns | Ns | Ns |
| E (RV) | 52.32±10.77 | 52±10.19 | 51.91±10.94 | | Ns | Ns | Ns |
| A (RV) | 34.05±6.84 | 33.32±6.41 | 33.95±6.95 | | Ns | Ns | Ns |
| RV GLS | -24.6±5.54 | -24.7±4.85 | -26.09±5.59 | | Ns | Ns | Ns |
| RV Med GLS | -23.91±5.32 | -24.29±4.68 | -25.79±5.61 | | Ns | Ns | Ns |

Legend: BMI: Body Mass Index; HR: Heart rate; EF: Ejection Fraction; LA: Left atrial diameter; IVS: interventricular septum; PW: Posterior Wall; LVEDD: Left Ventricle End Diastolic Diameter; LVESD: Left Ventricle End Systolic Diameter; CMI: cardiac Mass Index. *: statistically significant

SUPPLEMENTARY DIGITAL MATERIAL 2

Supplementary Table II.—Baseline global demographics and standard LV 2D echo parameters in RTR and HC trained at least 150 min/week of mixed exercise.

| Subjects | T0 | | | T6 | | | T12 | | |
|---|---|---|---|---|---|---|---|---|---|
| | RTR | HC | P | RTR | HC | P | RTR | HC | p |
| Age | 49.6±11.5 | 48.1±6.9 | Ns | 48.72±12.42 | 49.5±7.71 | Ns | 48.76±12.41 | 49.41±7.44 | Ns |
| Weight | 70.21±15.26 | 73.41±11.83 | Ns | 70.06±14.61 | 71.5±11.98 | Ns | 70.19±15.27 | 70.64±11.72 | Ns |
| Height | 168.55±11.72 | 175.32±8.70 | Ns | 168.69±11.75 | 175.32±8.70 | Ns | 168.69±11.75 | 175.32±8.70 | Ns |
| BMI | 24.57±3.81 | 23.14±2.21 | Ns | 24.47±3.50 | 23.32±2.31 | Ns | 24.48±3.55 | 23.04±2.06 | Ns |
| HR | 72.31±12.1 | 68.59±7.5 | Ns | 72±10.4 | 65.36±6.7 | Ns | 71±9.1 | 65.8±5.43 | Ns |
| SBP | 125.71±10.87* | 128.75±19.93* | 0.03 | 126.43±12.06* | 123.75±11.46* | 0.04 | 129.05±14.54* | 120.75±13.98* | 0.01 |
| DBP | 80.48±8.35* | 80.75±9.21* | 0.05 | 80.48±7.23* | 78.25±12.28* | 0.02 | 83.81±6.5* | 78.25±10.04* | 0.008 |
| EF | 60.13±5,3 | 57,74±3,2*§ | 0.007 | 61,57±6,7 | 59,3±1,9 | Ns | 64,38±6,0 | 60,36±4,2*§ | 0.001 |
| Aortic Root | 32.38±3.26 | 32.23±3.49 | Ns | 31.44±3.24 | 32.36±2.80 | Ns | 32.14±3.38 | 32.36±2.70 | Ns |
| LA | 37.41±3.83 | 35.18±3.66 | Ns | 37±4.07 | 35.55±3.74 | Ns | 38.21±4.11 | 35.41±3.83 | Ns |
| IVS | 9.68±0.70 | 8.72±0.77 | Ns | 9.71±0.62 | 8.84±0.84 | Ns | 9.69±0.56 | 8.92±0.68 | Ns |
| PW | 9.22±0.78 | 8.654±0.82 | Ns | 9.34±0.63 | 8.67±0.83 | Ns | 9.40±0.63 | 8.73±0.61 | Ns |
| LVEDD | 48.38±3.12 | 48.09±4.74 | Ns | 48.82±2.82 | 48.41±4.39 | Ns | 49.38±3.52 | 48.73±3.51 | Ns |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| LVESD | 29.38±3.13 | 28.68±4.26 | Ns | 28.64±4.12 | 29.14±3.56 | Ns | 28.97±3.85 | 29.5±2.97 | Ns |
| CMI | 106.25±18.16 | 89.65±18.30 | Ns | 108.14±11.32 | 90.51±20.54 | Ns | 112.39±13.58 | 92.12±17.72 | Ns |
| S/R | 0.40±0.09 | 0.35±0.03 | Ns | 0.37±0.02 | 0.35±0.03 | Ns | 0.38±0.03 | 0.35±0.03 | Ns |
| E | 75.83±17.33 | 74.18±14.98 | Ns | 73.11±18.52 | 70.59±13.96 | Ns | 74.52±17.09 | 72.91±18.37 | Ns |
| A | 67.35±18.71 | 48.09±14.55 | Ns | 67.3±16.61 | 50±12.97 | Ns | 69.86±14.54 | 55±15.64 | Ns |
| E/A | 1.12±0.34 | 1.66±0.55 | Ns | 1.18±0.51 | 1.49±0.52 | Ns | 1.08±0.23 | 1.44±0.52 | Ns |
| IVRT | 78.03±14.73 | 75.73±15.07 | Ns | 79.3±9.90 | 79.5±17.71 | Ns | 75.93±11.11 | 76.59±13.79 | Ns |
| DT | 195.05±36.30 | 182.98±34.54 | Ns | 190.95±40.61 | 187.37±25.98 | Ns | 196.82±36.96 | 184.43±31.58 | Ns |
| E1 | 9.43±3.46 | 10.5±1.92 | Ns | 10.08±2.74 | 10.36±2.01 | Ns | 10.34±2.84 | 10.82±2.24 | Ns |
| A1 | 9.9±2.18 | 10.68±2.42 | Ns | 10.12±2.60 | 10.18±2.72 | Ns | 10.24±3.11 | 10.91±3.24 | Ns |
| S | 7.83±1.28*# | 7.73±1.52* | 0.011 | 7.73±1.82*# | 8.45±2.22* | 0.009 | 9.48±2.90*# | 8.45±2.70* | 0.008 |
| MAPSE | 19±2.87 | 20.95±1.73 | Ns | 18.4±3.34 | 20.36±1.94 | Ns | 19.38±2.82 | 20.86±2.23 | Ns |
| E/E1 | 8.18±2.61 | 6.99±1.68 | Ns | 7.52±2.19 | 6.71±2.03 | Ns | 7.59±2.43 | 6.62±2.73 | Ns |
| LVGLS | -18.02±3.3*§ | -18.95±19*§ | 0.07 | -20.34±3.1*§ | -18.84±1.8*§ | 0.008 | -20.54±3.8*§ | -21.57±2.1*§ | <0.001 |
| LVMedGLS | -18.56±3.79*§# | -19.09±2.01*§° | <0.001 | -20.21±3.05*§# | -18.37±1.31*§° | 0.001 | -20.48±2.95*§# | -20.92±1.84° | 0.07 |

Legend: RTR: Renal Transplant Recipients; HC: Healthy Control;BMI: Body Mass Index; HR: Heart rate; EF: ejection Fraction; LA: Left atrial diameter; IVS: interventricular septum; PW:

Posterior Wall; LVEDD: Left Ventricle End Diastolic Diameter; LVESD: Left Ventricle End Systolic Diameter; CMI: cardiac Mass Index; MAPSE: Mitral Annular Plane Excursion; RWT: Relative Wall Thickness; E/A: E wave; A wave.HR: Heart Rate; SBP: Systolic Blood Pressure; LV GLS: Left Ventricle Global Longitudinal Strain; LV Med GLS: Left Ventricle Medium Global Longitudinal Strain; EF: Ejection Fraction. Data are expressed as Mean±SD. *: significance between subject factors; §: significance within subject factors; #: significance within RTR group; °: significance within HC group