

Effects of a transoceanic rowing challenge on cardiac function, and respiratory and muscular fitness

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Key words

cardiopulmonary exercise test, echocardiogram, veteran athletes, cardiovascular risk, sports cardiology, ultra endurance rowing

accepted 31.10.2023

accepted manuscript online 06.11.2023

published online 2024

Bibliography

Int J Sports Med

DOI 10.1055/a-2205-1849

ISSN 0172-4622

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Georg Thieme Verlag, Rüdigerstraße 14, 70469 Stuttgart, Germany

Abstract

Introduction: Ultra-endurance sports and exercise events are becoming increasingly popular for older age groups. We aimed to evaluate changes in cardiac function and physical fitness in males aged 50-60 years who completed a 50-day transoceanic rowing challenge. **Methods:** This case account of four self-selected males included electro- and echo-cardiographic (ECG, echo), cardiorespiratory and muscular fitness measures taken between nine-months prior to and three weeks after a transatlantic team-rowing challenge. **Results:** There were no clinically significant changes to myocardial function found over the course of the whole study period. The training and race did create some expected functional changes to left ventricular and atrial function; the former associated with training, the latter likely due to dehydration, but both resolving towards baseline within 24-hours to three weeks post-event. From race-start to finish all four rowers lost 8.4-15.6 kg of body mass. Absolute cardiorespiratory power and muscular strength were lower at three weeks post-race compared to pre-race, but cardiorespiratory exercise economy improved in this same period. **Conclusions:** A structured programme of moderate-vigorous aerobic endurance and muscular training for > 6 months, followed by 50-days (10-12 hours per day) of transoceanic rowing in older males proved not to cause any observable acute or potential long-term risks to cardiovascular health. Pre-event screening, fitness testing, and appropriate training support is recommended, especially in older participants where age itself is an increasingly significant risk factor for potential acute and chronic health events.

Introduction

In the past 25 years there has been a large increase in the participation of ultra-endurance events, with growing numbers in the senior age categories. [1] The effects of training and competition in endurance and ultra-endurance athletes on cardiac health and function have been reported in two general areas: i) the evaluation of myocardial health changes from exposure to long-term (i.e. decades) high-volume training and competitions; and ii) acute post-event responses, recorded through the prism of biochemical, histological, and electrophysiological changes. [2, 3] Overall, in this evidence, a single event usually only poses the risk of triggering an acute cardiac event if there is an underlying (manifest or silent) clinical condition, whereas long-term repeated bouts of high-volume intense training and competition may lead to the development of de-novo pathology. [4] With ageing populations in Western Europe and North America, and the popularity amongst this demographic of taking-up personal challenges linked with raising money for charitable purposes, there continues to be increasing numbers of older recreational participants entering ultra-endurance competitions.[5] A coupling of the natural effects of ageing on cardiovascular health and the time-availability for older adults to train for and participate in ultra-endurance events has been shown to increase the acute risk of non-fatal and fatal cardiac events during and soon after participation. [6] Event organisers are therefore increasingly aware of the importance to plan for and mitigate against these predictable risks prior to and during events, especially when undertaken in remote environments. [7, 8]. The existing range of reported health conditions for transoceanic rowing have included dermatological, musculoskeletal, seasickness, return-to-land-sickness, gastrointestinal, loss of appetite, febrile illness, dental, mental health, urological, respiratory tract infection, nose-bleeds, haemorrhoids, and dehydration [8]

Most of the cardiovascular health research on ultra-endurance events has been in running and cycling with relatively few reports for long-distance rowing. [9, 10] Of increasing popularity are transoceanic rowing events (especially as individuals, pairs or in teams of three and four). A cross Atlantic Challenge is prominent in this category; covering 5000 km and taking 30-90 days to complete. Whilst there is evidence of chronic changes to cardiac morphology in typically trained elite rowers, [11] the evidence on acute and chronic cardiovascular responses in ultra-long-distance rowing competitors has been limited to cardiac biochemical markers (Table 1.). [9, 10, 12, 13] Evaluations of myocardial function via echocardiography in older recreational participants of trans-oceanic rowing challenges are yet to be performed. Consequently, it was the aim of this current prospective case-study to evaluate whether a 5000 km transoceanic row in recreational male participants aged over 50 years would sustain any acute and potentially chronic detrimental changes to myocardial function and morphology, along with any coinciding changes in cardiorespiratory and muscular fitness.

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Methods

Study design

This was a repeated measures prospective case-account of four individual participants' cardiac functions, and cardiorespiratory and muscular fitness (Figure 1). The key areas of measurement were: resting and exercise electrocardiogram (ECG), echocardiography, and cardiorespiratory and muscular fitness. All measures were taken between nine-months pre-race and two-months post-race. The study commenced following University ethics committee approval and followed by similar agreement with the race organisers.

The participants were four self-selecting males aged between 50 and 59 years, who had already registered for the Atlantic Rowing Challenge and who sought health screening and training advice for the final nine-months leading up to the race commencement.

Electrocardiography and Echocardiography

Telemetry monitored resting and exercise ECGs (Custo Med, Ottobrunn) were performed and evaluated using standard procedures. [14] The exercise ECG used a ramp protocol on a cycle ergometer (Lode-Corival, Groningen) to a maximal volitional or symptom limited end. [15] Successful completion of the cycle ergometer test without clinical cardiopulmonary symptoms or clinically significant ECG changes was used to

clear participants to perform a maximal rowing ergometry cardiopulmonary fitness test either on the same day following at least two-hours rest or within 7-days.

The resting echocardiograms were performed as per the British Society of Echocardiography (BSE) guidelines [16] using a Vivid iq portable echocardiogram (GE Health Medical, Chicago). The time points of each assessment were: 6-9 months pre-race, 3-weeks pre-race, 1-2 hours post-race, 24-hours post-race, and 3-weeks post-race. To minimise inter-trial measurement variability the same operator (British Society of Echocardiography accredited with >20 years of experience) performed all five assessments. Blood pressure was measured during acquisition of left ventricular (LV) stroke volume (SV) Doppler recordings as part of determining LV systolic elastance.

Cardiac measurements and calculations were determined off-line using GE Echopac software (GE Health Medical, v203 2019). LV septal/posterior wall thickness in diastole (IVSd/LVPWd), LV internal diameter in diastole (LVIDd), and RV basal diameter were measured using two-dimensional caliper measurements. LV systolic/diastolic volume, and LA volume were calculated using the modified Simpson's biplane method. From these measures the following parameters were derived: LV mass (g), relative wall thickness ratio, and LVEF. Doppler derived measurements included: mitral inflow peak E wave velocity, R wave to flow onset / flow end, LV outflow tract velocity time integral, LV stroke volume (SV), and E/E' LV filling ratio. Tissue velocity imaging (TVI) was used to determine peak annular velocities of the LV lateral, LV septal, and RV annular wall regions. LV global longitudinal strain (GLS) was calculated using speckle-tracking [automated functional imaging; [17] GE Health Medical].

Left ventricular end-systolic elastance

Left ventricular end-systolic elastance (E_{es}) was calculated by a modified single-beat method [18] using systolic (P_{es}) and diastolic (P_d) blood pressure (non-invasive arm-cuff measurements), and the following echo-derived measurements: SV, pre-ejection period (R wave to flow-onset), total systolic period (R-wave to flow-end), left ventricular ejection fraction (LVEF), SV.

Assessments of cardiorespiratory and muscular fitness

Cardiorespiratory fitness

There were two elements to the assessment of cardiorespiratory fitness during rowing ergometry (Concept2D Morrisville, Vermont, US): i. maximal aerobic power (VO_2max) and ii. rowing economy (VO_2 at a rowing pace of 2:15 mins:sec per 500m). Both VO_2max and VO_2 economy were assessed by continuously measured pulmonary gas exchange (Cortex Metalyzer 3B, Leipzig). The incremental VO_2max testing protocol was based on the core principle that the test should not exceed 8-10 minutes [19]. A variety of reports have used incremental rowing ergometer testing stages of one to three mins [20]. We chose two-minute stages as we also wished to use the test to determine near-steady-state heart-rate rowing speed relationships for setting subsequent individualised participant training intensities. Each participant was asked to state what he felt was his maximum 500 m rowing split-time, for which he could not sustain for more than 30 secs, and we then backwards-calculated 5 x 2 min stages from this pace, in equal increments of 500 m split times. As the maximum speed estimate was very similar for all participants, the 1st 2-min testing stage (500m split-time pace) was backwards calculated to 2:45 sec/500 m. The overall test involved three testing phases:

- i. *A 5 min warm-up phase*, commencing at a rowing pace of 3:00 mins/500m, followed by successive pace increments every two minutes by 15 secs/500m until the participant reached a pace of 2:15 mins/500m (the pace for assessing economy),
- ii. *VO_2 rowing economy phase*, where participants maintained a pace of 2:15 mins/500m for 10 mins; the rowing participants chose this pace, as it was their average indoor training pace for endurance sessions >60 mins,
- iii. *The final moderate to maximal testing phase starting from 2:15 mins/500m*, again had the participants increment the pace by 15 secs/500m every two minutes until volitional fatigue. Participants were encouraged to persist to the point of volitional fatigue with the aim to elicit a respiratory exchange ratio >1.2 and/or a plateau in VO_2 was observed [19].

Muscular fitness

Maximal strength was measured by three assessments: a bench press (one-repetition maximum) and two isometric function tests consisting of a bilateral quadriceps seated leg extension and a static “squat” deadlift. Both isometric tests used a fixed cable attached between the force-arm and electric tensiometer to measure static force (ADInstruments Dunedin, NZ; Sensor Techniques, Cowbridge, Wales).

Rowing event performance strategy

In keeping with previous teams performing this same transoceanic challenge, the daily strategy involved two rowers performing for two-hours, followed by two hours of rest. [9] However, one rower would perform for four hours once every third pairing cycle, so as to achieve a longer rest period.

Results

The four rowers were all retired army officers. Rowers 1, 2 and 3 prepared for this event with two years of regular endurance rowing and strength training. Rower 4 joined the team and commenced focused training 6 months prior to race commencement. All were generally active and “sporty” throughout their lives, but none were either long-term competitive rowers or specific endurance athletes. All four were aged between 50 and 59 years at the time of assessment, and some with age-related asymptomatic comorbidities (Table 2.).

They completed the transatlantic challenge in 50 days and 19 minutes which earned them a finishing place of 25th out of 35 teams. All rowers remained relatively healthy throughout the pre-race assessment period and during the race with coinciding reductions in body mass and blood pressure (Tables 3 and 4). Three months prior to race commencement, Rower 1 had a relapse in his multiple myeloma status (Figure 5; Table 2). In the three weeks between race completion and the final fitness assessments performed in the UK, all rowers had ceased regular exercise or training of any type.

From three weeks pre-race to the day of race completion all four rowers had a reduction in body mass between 8.4 and 15.6 kg (Table 4). Body mass regain between race-end and three weeks post-race occurred in all rowers ranging from +5.6 to +10.1 kg, which put them within 1 to 10 kg of their pre-race body mass.

Echocardiography results (Tables 2 and 3) at 6-9 months and three weeks pre-race excluded any significant underlying structural heart disease in the rowers with the exception of Rower 2 who was known to have a bicuspid aortic valve with mild aortic regurgitation. Rower 2 underwent some additional precautionary pre-race cardiac investigations including an additional treadmill ECG stress test, a coronary angiogram and a thoracic aorta magnetic resonance imaging (MRI) scan, followed by the prescription of a beta-blocker and statins. The current echocardiograms confirmed that no significant changes in echocardiographic parameters had occurred compared to his previous routine measures and the MRI of his aorta excluded an aortaopathy. After the institution of therapy, a follow-up maximal treadmill exercise stress test “on beta-blockers” continued to demonstrate a low-level risk profile.

At race completion, the requisite examination by the race organiser’s doctor reported no significant medical concerns in any of the four rowers. The rowers reported having no symptoms during the race that could be related to a potential cardiac event and compared to pre-race measures, overall the echocardiogram results reported showed no sub-clinical evidence of cardiac damage or dysfunction in any of the rowers (Table 3; Figures 4-7). The baseline health status and time-point echocardiographic measures are summarised in Table 3A-D-d. Echocardiographic measures which demonstrated a change included: LA volume, LVEF, GLS, and LV elastance (Figures 1-4).

Cardiac dimensions and volumes

The LV mass and LV chamber volumes did not show any significant change across the study points. RV cavity dimensions remained within normal ranges across all study points.

LA volumes (Figure 1) showed a tendency to increase following training, a well-established phenomenon in endurance training. Although there were signs of LA volume recovery between 24 hours to 3-weeks post-race, all LA volumes remained lower compared to pre-race values.

Left ventricular function

The LVEF (Figure 2) remained within normal limits throughout all study points. Tissue Doppler imaging-derived LV systolic velocities also remained within normal limits with a small increase at the race finish and 24hr post-finish study points. GLS (Figure 3) values remained stable with no change at the study end point compared to baseline.

Left ventricular end systolic elastance

There was no detectable pattern change in the LV elastance (Figure 4) values across the five study points. Equally there was no detectable change in mean LV elastance between the pre-race and post-race values.

Right ventricular function

Right ventricular (RV) peak systolic velocity remained unchanged across all time points (TDI RV peak S).

Cardiorespiratory and muscular fitness

A summary of the rowers' changes to both absolute and relative (per kg) aerobic power (VO_2max) and their maximal arm and leg strength are summarised in Figures 5 to 7 and Table 4. With the exception of Rower 1, who had experienced a relapse of his myeloma, all other rowers improved their aerobic power in the 6 to 9 months period leading up to the race start.

At three weeks post-race,, compared to pre-race values, all rowers showed a reduction in absolute VO_2max = (0.2 and 0.6 $\text{l}\cdot\text{min}^{-1}$) and relative VO_2max (0 to -7.0 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)

Rowing economy, over the 6-9 months of pre-race training, improved in all four rowers and this improvement was sustained compared at three weeks post-race detraining (Table 4)

Changes to muscular strength followed similar patterns to aerobic power in the four rowers (Figures 6 and 7, Table 4). With the exception of Rower 2's bench press 1-RM decreasing in the 9 months pre-race, all measures of strength declined between race start and three weeks post-race. The proportions of strength loss from race-start to post-race were: 5 – 22% for bench-press; 20-26% for the isometric thigh extension; and 5 – 12% for the isometric squat.

Discussion

This case-report summarises the cardiovascular and fitness changes in four males (50-60 years), who undertook a moderate intensity high volume of pre-competition training and then completed a single transoceanic rowing event. The measures evaluated cardiovascular and muscle physiological health effects of up to two years training and then performing 50 consecutive days, 10-12 hours per day of light to moderate-intensity transoceanic rowing, as estimated by previous reports.[21] It also needs to be appreciated that the physiological responses reported must also consider any influences of the participants' psychosocial challenges linked to being confined to a small living environment, rough weather and sea, and many weeks of low sleep quantity and quality.[8] Any measured declines in cardiac functioning following this event, were generally resolved within 24 hours to 3 weeks post-event. There were parallel declines in both aerobic power and muscular strength. Given that ageing, independent of training, leads to a natural decline in peak fitness, this report helps to raise the value of recommending that older participants need to maximise their pre-event fitness; where any absolute loss in functional fitness during and after such an event is proportionally greater compared to the same absolute loss in a younger/fitter participant. [22]

Cardiac function

LV systolic function remained within the normal range [23] for all rowers at all measurement points. The GLS (Figure 3), which is considered the most accurate and sensitive marker for early detection of myocardial dysfunction [24] and as a predictor of long-term risk of cardiovascular morbidity and mortality in men [25], remained unchanged between race start to completion and three-weeks post-race. An area which is hypothesised for further investigation is, that unlike much shorter but higher intensity endurance rowing events of 12-24 hours where there are no (or little) rest periods, that the taking of regular two-to-four-hour rests during this ultra-endurance event could act to prevent any negative cardiac strains.

Atrial function

The one echocardiographic measure to show a marked change was LA volume (Figure 1). In the 6-9 months of pre-race training, LA volume increased in three of the four rowers, reflecting similarly reported adaptations to elite rowers. [26] However, compared to pre-race measures, LA volumes at the end of the race were reduced in three of four rowers and remained in all rowers at three weeks post-race. The rower who did not display this pattern was the one with myeloma, but determining whether this was a coincident or causative effect would require further evaluation. A reduced LA volume at race completion is expected and linked to dehydration, which reduces systemic venous return and corresponding cardiac filling. [27, 28] Within 24 hours of race completion and corresponding rehydration, LA volume showed an increase (recovery) and coincided with similar and expected post-race recovery patterns in both LVEF (improved 6-14%) and LV end systolic elastance (Figures 2 and 4). [29] We know that in this age group, LA size can increase as an early marker of left ventricular pathology. [30] However, it seems unlikely that the transient changes observed in LA size, due to this rowing event, relate to the development of any cardiac pathology, given that at 24-hours post-event atrial size began to regress and remained in a normal range three weeks later (Figure 1).

Ventricular function

Following 6-9 months of pre-race endurance training, LVEF decreased in three of the four rowers, which has previously been reported as a typical fitness related change that is normally non-clinically significant. [31] At the end of the race compared to pre-race, LVEF had decreased in two rowers but increased in the other two. In the two where LVEF increased pre-to-post race, one was the rower with the bicuspid aortic valve and the other was the rower who only had six months of pre-race training. Whether clinically significant or not, GLS pre-race to 24 hours post-race remained suppressed in all rowers but recovered to pre-training/pre-race levels in all rowers at three weeks post-race (Figure 3).

The lack of any lasting reduction in GLS, LVEF, or TVI measurements excludes a pathological cause/concern for the observed drop in LV systolic elastance. Because of the total period of focused regular high volumes of endurance training in three of the rowers was less than three years, it would appear that unlike very long-term high-volume endurance athletes, our group are at a low risk of developing exercise related cardiac pathologies. [4]

Future studies in cardiac function

We plan to recruit more teams into this study for the future, in order to see if there are more generalisable patterns of responses. With the advancement of technology, it is hoped to record some physiological responses during these types of events (i.e. heart rates, ECGs, blood

pressures, energy expenditure and work outputs and potentially, blood samples). A cardiac MRI pre- and post-race could be advantageous to allow for a more detailed and sensitive assessment of cardiac muscle morphology and systolic function, especially in further investigating the changes to atrial function and size. Future studies could incorporate the use of atrial strain/function analysis.

Body composition, Cardiorespiratory and Muscular fitness

There is only one other study by Keohane et. al., (2019) [9] that has reported on changes in anthropometric and fitness parameters following this same Atlantic Ocean rowing challenge. They reported on a team of four young adult males (26.5 ± 1.9 years) who on race completion had a mean weight loss of 5.5 kg that ranged up to ~11kg. In our four older male participants, weight loss was greater and ranged from 8 to 15 kg (median 11kg). At two weeks post-race Keohane et al. reported that body mass had returned to within 1 kg of pre-race levels; in our older male participants, at three weeks post-race two rowers were within 1.5 kg of pre-race mass but the other two still remained much lighter by 8.5 and 10 kg. The lower mass loss and greater return to pre-race levels in the Keohane cohort could be a function of them being well-trained endurance athletes, with established athletic lifestyles and nutritional behaviours that required them to return to regular training for future competitive events. [9] When the body mass loss in our older men was adjusted relative to pre-race mass (94 kg) versus the same for Keohane et al's cohort (83 kg)[9], our rowers had an 8% mean mass loss versus 6% in the younger rowers.

For pragmatic reasons, taking fitness measures at race completion or within 24 hours was not possible, which delayed post-race measures until they returned to the UK three weeks later. Our participants (at three weeks post-race) lost almost twice more aerobic power (-3.2 ml/kg/min) than those of Keohane et al. at two weeks post-race (-1.5 ml/kg/min). As with the body mass loss, this could be a function of a greater amount of detraining of our older participants who completely ceased all exercise in this period and with one more week occurring before testing was performed,.. In acknowledging that body mass loss can make it appear there has been changes in relative aerobic power, it must be noted that rowing is mainly a non-weight-bearing seated activity that is generally performed on a level grade. Therefore, the absolute aerobic power is likely to be a more valuable assessment when reviewing our results. Of interest, the lowest aerobic power scores were found in our two participants with prominent medical conditions (myeloma and heart-valve dysfunction), yet they had the lowest declines in fitness of 7 and 8%, respectively, whereas the two aerobically fitter participants had declines of 14 and 17%, respectively.

A recognised area of linking aerobic function to endurance performance as a more precise predictor than $\text{VO}_{2\text{max}}$, is movement economy. [32-34] Hence, in counteracting some of the possible losses in aerobic power following the race, all four rowers had improved rowing economy during the 6-9 months pre-race period, and much of this was preserved even with three weeks post-race detraining (Table 4).

This is the first known study to report on changes in muscular strength following a transoceanic rowing endurance event. There was a loss of absolute muscle strength between race start and three weeks post-race..

Considerations for future studies

There was one important oversight in measurements of muscular strength needing evaluation in the future, which is one that mimics the composite “catch and pull” action of the rowing stroke involving forearm flexors, shoulder extensors and scapular retractors.

In rowing a consensus and agreed set of guidelines on maximal testing protocols, compared to traditional cycle ergometer and treadmill tests, appears to be required to reduce potential debates on measurement reliability and validity. In our protocol, we chose to use rowing speed because this was convenient and familiar to our participants, and yet led to an oversight that VO_2 grows in a positive curvilinear fashion as a function of speed at a fixed resistance [35]. Hence the five testing stages were not equal increments if expressed as Watts (~25, 40, 60, 100 Watts). In order to determine a truer explanation of decline in cardiac function, aerobic power and muscular strength, there may now be technology that can be used to capture in-race physiological strain during the actual event. Furthermore, being able to capture fitness measures within 48 – 72 hours post-race could help resolve debates about whether post-race loss of fitness as being a function of the race itself or that of post-race detraining.

Conclusions

In four older male participants who have specifically trained for less than three years and then completed a transoceanic rowing race, this volume and type of light to moderate intensity activity over 7 weeks appears to have had little negative impact on acute or shorter term chronic myocardial health. Any event-related myocardial changes which could theoretically be associated with a longer-term risk, were resolved within 24 hours to three weeks post-event. As age in itself is a strong predictor of an exertion-related acute cardiovascular event, medical and fitness screening seems prudent to mitigate such events. These four older male participants have demonstrated that following previously published (and race-organiser) recommendations on nutrition and daily strategies around activity and rest proved to be successful and mitigated any negative cardiovascular health problems. This then highlights that for older participants competing in such events in remote environments, the value of a full cardiovascular assessment at rest and under exertional stress is certainly warranted. Especially true where there were two participants in this report with potentially risky health conditions, whose health screening raised the need for additional medical evaluations. In light of the risks of transoceanic rowing, augmented by age and some specific health conditions, this case report demonstrates that screening and training support from an exercise medicine team can provide participants, their relatives and the event organisers with some reassurance of reducing controllable risks to health.

Data availability statement

The data underlying this article will be shared on reasonable request to the corresponding author.

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Captions for Figures

Figure 1: Left Atrium (LA) volume between 6 to 9 months pre-race and three weeks post-race

Figure 2: Left Ventricular Ejection Fraction (LVEF%) between 6 to 9 months pre-race and three weeks post-race

Figure 3: Global Longitudinal Strain (GLS) between 6 to 9 months pre-race and three weeks post-race (Note: an increasing negative value shows an increasing systolic function)

Figure 4: Left ventricular (LV) end systolic elastance between 6 to 9 months pre-race and three weeks post-race

Figure 5. Absolute maximal aerobic power (l.min⁻¹) between 6 to 9 months pre-race and three weeks post-race

Figure 6. Upper-body strength (maximal bench press) between 6 to 9 months pre-race and three weeks post-race (*estimated from reverse extrapolation)

Figure 7. Isometric thigh strength (quadriceps knee extension) between 6 to 9 months pre-race and three weeks post-race (*estimated from reverse extrapolation)

Captions for Tables

Table 1. Known published reports on cardiovascular response measures related to cardiac strain from long-distance rowing.

Table 2 Cardiologist’s baseline screening summary

Table 3A – D
Time-point echocardiographic function assessments

Table 4. Relative cardiorespiratory fitness, rowing economy, and isometric leg squat force

Table 1. Known published reports on cardiovascular response measures related to cardiac strain from long-distance rowing.

Authors	Distance rowed	Participant demographic	Cardiovascular measures
Keohane et al., 2019	5000 km	N = 4; 26.5 ± 1.3 yrs	Biomarkers of inflammation, body composition and cardiorespiratory fitness
Frias et al., 2018	160 km	N = 5; 43 – 46 yrs, healthy	Biomarkers of inflammation and cardiac strain
Jurimae et al., 2016	21 km	N = 20; 19 ± 3 yrs; competitive rowers	Biomarkers of inflammation and cardiac strain

Legaz-Arrese., 2015	30 min, ^{high} intensity	N = 18 elite; 14 amateur rowers	Biomarkers of inflammation and cardiac strain
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Table 2. Cardiologist's baseline screening summary

Health Parameter	Rower 1	Rower 2	Rower 3	Rower 4
Age (yrs), Height (cm), Mass (kg)	59, 181.6, 99.7	57, 176.2, 86.4	54, 193.5, 120.5	59, 181.0, 97.5
Clinical history	Multiple myeloma (BM transplant and chemo)	Hypertension (med-controlled), bicuspid aortic valve	No previous medical history of note.	Familial hypercholesterolaemia (controlled with medication)
CV Examination	Normal	Soft ejection murmur, normotensive	Normal	Normal
Resting-ECG	Normal	Sinus rhythm, mild left-axis deviation	Normal	Occasional unifocal ventricular ectopic, otherwise normal
Resting Echocardiograph	Mild LV diastolic dysfunction	Bicuspid aortic valve, calcified appearance (non-sig. haemodynamic aortic stenosis), mild aortic regurgitation. Normal aortic root dimensions. Normal LVEF and chamber size. Mild LV diastolic dysfunction. MRI of aorta normal	Normal	Normal
Maximal Exercise ECG	Normal	See results section on follow-up cardiac investigations	Normal	Normal - Ventricular ectopic beat resolved on exercise

Table 3A – D

Time-point echocardiographic function assessments

A. Rower 1	6-9 Months Pre-race	3wks Pre-race (UK)	Race finish- line (Antigua)	24hrs post-race	19 days post-race (UK)
Resting HR (beats/min)	65	70	71	84	82
Systolic BP (mm/Hg)	145	155	125	122	137
Diastolic BP (mm/Hg)	75	90	80	79	76
IVSd (mm)	12	12	11	11	11
LVIDd (mm)	50	49	50	49	49
LV mass (g)	233	196	215	202	177
LVEDV (ml)	86.4	86	88	82.5	81.9
TDI septal peak S (cm/s)	7.8	7.6	7.9	8.9	7.9
TDI lateral peak S (cm/s)	10	9.7	9.2	9.7	9.6
E/e'	7.7	8.8	6.6	7.1	8.1
RV diameter (mm)	34	35	39	37	33
TDI RV peak S (cm/s)	12.4	11.5	12.4	11.1	11.8

B. Rower 2	6-9 Months Pre-race	3wks Pre-race (UK)	Race finish- line (Antigua)	24hrs post-race	19 days post-race (UK)
Resting HR (beats/min)	66	55	64	72	68
Systolic BP (mm/Hg)	125	130	115	108	119
Diastolic BP (mm/Hg)	79	70	61	56	78
IVSd (mm)	11	10	11	11	11
LVIDd (mm)	45	51	48	45	48
LV mass (g)	194	182.8	222	202	220
LVEDV (ml)	128	141	140	127	143.7
TDI septal peak S (cm/s)	7.7	7.8	6.9	11	8
TDI lateral peak S (cm/s)	8.5	7.9	7.6	10	9.1
E/e'	8.4	10	8.2	6.1	10.8
RV diameter (mm)	34	38	35	35	35
TDI RV peak S (cm/s)	11.8	11.6	14.3	14.3	11.8

C. Rower 3	6-9 Months Pre-race	3wks Pre-race (UK)	Race finish- line (Antigua)	24hrs post-race	19 days post-race (UK)
Resting HR (beats/min)	58	62	95	75	85
Systolic BP (mm/Hg)	145	120	126	114	114
Diastolic BP (mm/Hg)	75	70	73	77	61
IVSd (mm)	12	11	11	11	11
LVIDd (mm)	53	53	43	47	48
LV mass (g)	249	239	180	196	203
LVEDV (ml)	121	121	89	90	100
TDI septal peak S (cm/s)	9.1	8.1	9.2	10.5	10.7
TDI lateral peak S (cm/s)	9	9.1	8.1	11.1	10
E/e'	8.5	8.1	6	5.3	4.8
RV diameter (mm)	36	36	31	32	32
TDI RV peak S (cm/s)	11.2	10.3	15	9.9	14.2

D. Rower 4	6-9 Months Pre-race	3wks Pre-race (UK)	Race finish- line (Antigua)	24hrs post-race	19 days post-race (UK)
Resting HR (beats/min)	61	62	65	70	65
Systolic BP (mm/Hg)	130	138	134.00	132	133
Diastolic BP (mm/Hg)	80	85	87	86	83
IVSd (mm)	11	11	11	11	11
LVIDd (mm)	58	59	56	58	56
LV mass (g)	283	302	267.5	255	272
LVEDV (ml)	154	155	118	116	143
GLS (%)	-17.1	-16.4	-17.4	-19	-18.3
TDI septal peak S (cm/s)	8.4	6.1	7.6	8.4	8.1
TDI lateral peak S (cm/s)	9.6	7.8	8.1	8.1	9.4
E/e'	4.7	6.5	6.2	5	6.6
RV diameter (mm)	39	41	37	36	39
TDI RV peak S (cm/s)	12	11.2	13.2	11.4	12

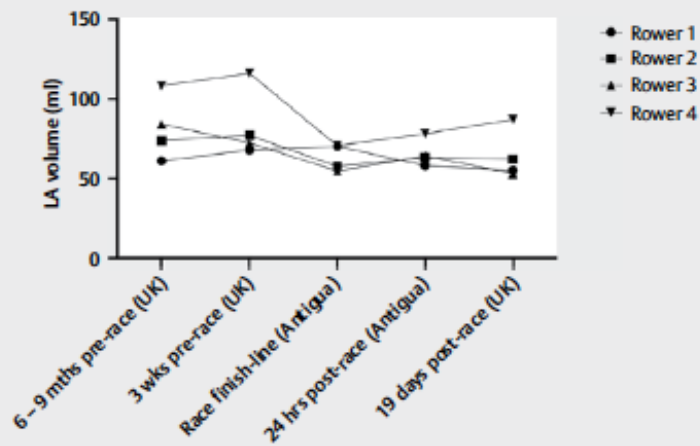
Table 4. Relative cardiorespiratory fitness*, rowing economy, and isometric leg squat force

	6-9 mths pre-race UK	3 wks pre-race UK	50 days Race finish Antigua	3 wks post-race UK
Body mass kg				
Rower 1	99.7	102.0	86.6	93.6
Rower 2	86.4	84.7	75.3	83.1
Rower 3	120.5	116.6	101.0	106.6
Rower 4	97.5	94.7	83.4	93.5
Mean**	101.1	99.5	88.6	94.2
VO₂max ml/kg/min*				
Rower 1	29.0	27.0		27.5
Rower 2	37.0	39.0		36.6
Rower 3	30.0	35.0		32.0
Rower 4	36.0	40.0		33.0
Mean**	33.0 (4.1)	35.3 (5.3)		32.3 (3.7)
VO₂ economy (l/min)				
†				
Rower 1	2.6	2.2		2.5
Rower 2	2.8	2.2		2.3
Rower 3	2.7	2.6		2.3
Rower 4	2.6	2.1		2.2
Isometric Leg Squat force (N)				
Rower 1	1404.7	1233.0		1170.0
Rower 2	984.5	948.8		838.2
Rower 3	1537.8	1408.1		1342.3
Rower 4	1330.4	1340.2		1174.0

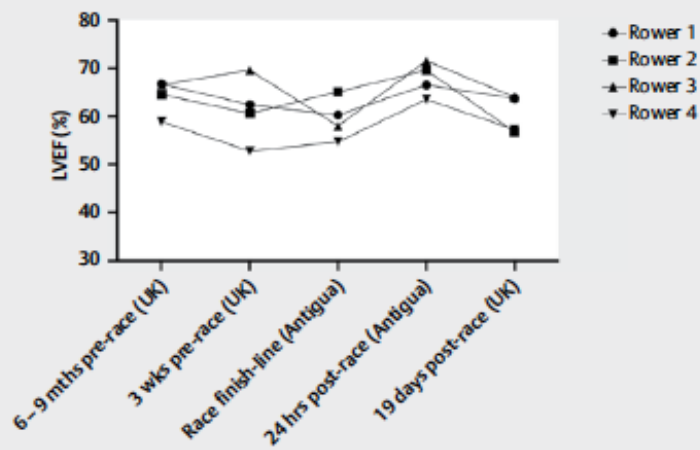
*Absolute VO₂max values are presented in Figure 5.

**Means calculated for comparative purposes with other studies

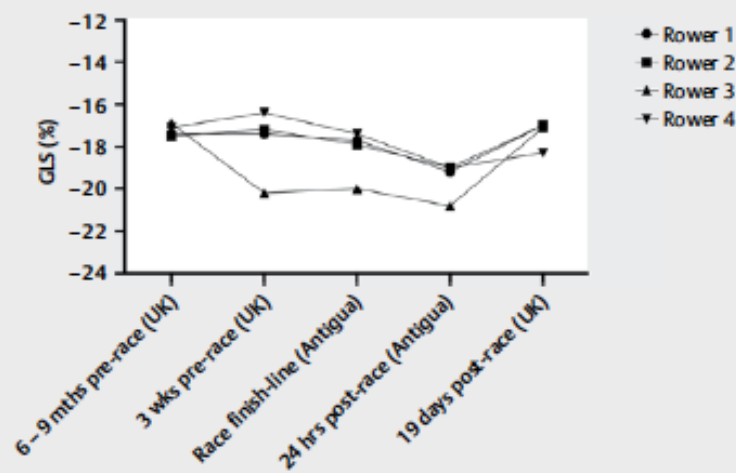
†VO₂ economy at ergometer pace of 2:15min/500m (a lower score is better)



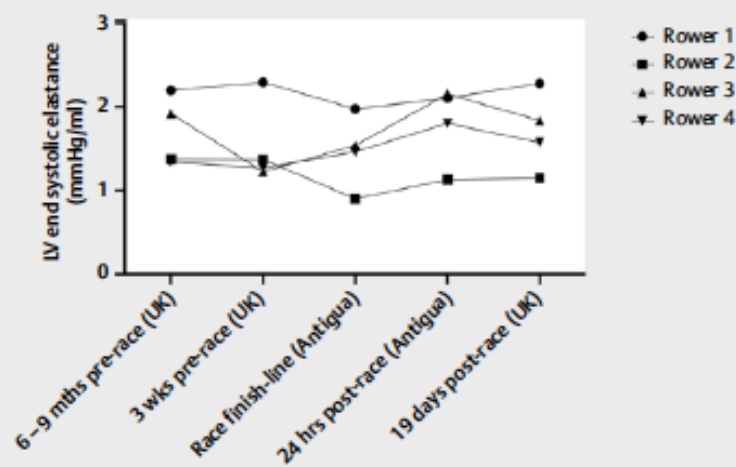
► **Fig. 1** Left Atrium (LA) volume between 6 to 9 months pre-race and 19 days post-race.



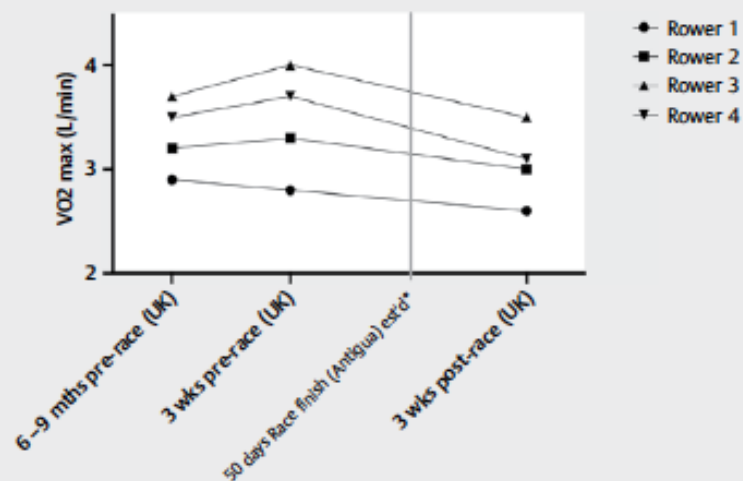
► **Fig. 2** Left Ventricular Ejection Fraction (LVEF %) between 6 to 9 months pre-race and 19 days post-race.



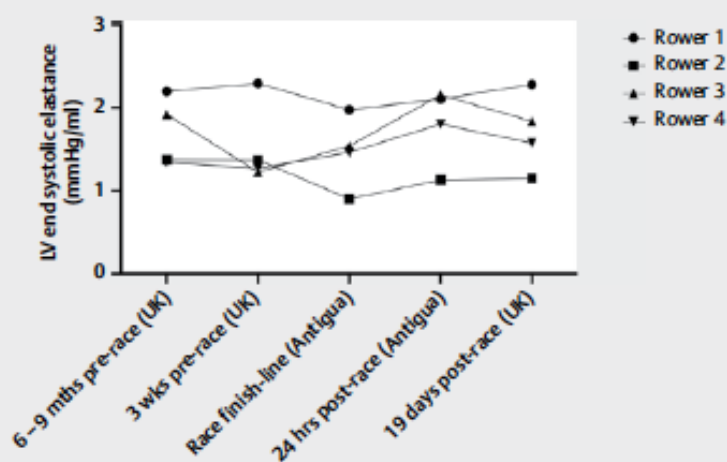
► **Fig. 3** Global Longitudinal Strain (GLS) between 6 to 9 months pre-race and 19 days post-race (Note: an increasing negative value shows an increasing systolic function).



► **Fig. 4** Left ventricular (LV) end systolic elastance between 6 to 9 months pre-race and 19 days post-race.



► **Fig. 5** Absolute maximal aerobic power ($\text{l}\cdot\text{min}^{-1}$) between 6 to 9 months pre-race and three weeks post-race.



► **Fig. 4** Left ventricular (LV) end systolic elastance between 6 to 9 months pre-race and 19 days post-race.