

## COPYRIGHT NOTICE



### FedUni ResearchOnline

<https://researchonline.federation.edu.au>

This is the published version of:

Knox, A., Sculthorpe, N., Grace, F. (2019) Caucasian and south Asian men show equivalent improvements in surrogate biomarkers of cardiovascular and metabolic health following 6-weeks of supervised resistance training. *F1000Research*, 7, p. 1-16.

Available online at <https://doi.org/10.12688/f1000research.15376.2>

Copyright © 2019 Knox, A., et. al. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0) (<http://creativecommons.org/licenses/by/4.0/>). The use, distribution or reproduction in other forums is permitted, provided the original author(s) or licensor are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.



RESEARCH ARTICLE

**REVISED** **Caucasian and south Asian men show equivalent improvements in surrogate biomarkers of cardiovascular and metabolic health following 6-weeks of supervised resistance training [version 2; peer review: 2 approved]**

Allan Knox<sup>1</sup>, Nicholas Sculthorpe<sup>2</sup>, Fergal Grace <sup>3</sup>

<sup>1</sup>Exercise Science Department, California Lutheran University, Thousand Oaks, CA, 91360, USA

<sup>2</sup>Institute of Clinical Exercise and Health Science, University of the West of Scotland, Hamilton, South Lanarkshire, ML3 0JB, UK

<sup>3</sup>School of Health Science and Psychology, Federation University, Ballarat, Victoria, 3350, Australia

**v2** **First published:** 24 Aug 2018, 7:1334 (<https://doi.org/10.12688/f1000research.15376.1>)  
**Latest published:** 05 Mar 2019, 7:1334 (<https://doi.org/10.12688/f1000research.15376.2>)

**Abstract**

**Background:** The South Asian population have greater cardiovascular risk than their age-matched Caucasian counterparts, characterized by unfavorable biomarkers. South Asians may also be partially resistant to the pleiotropic benefits of physical activity on cardiovascular health. There is a current absence of studies that compare markers of cardio-metabolic health between Caucasians and South Asians employing resistance exercise. This study set out to compare the response in biomarkers of cardio-metabolic health in Caucasians and South Asians in response to resistance exercise.

**Methods:** Caucasian (n=15, 25.5 ± 4.8 yrs) and South Asian (n=13, 25.4 ± 7.0 yrs) males completed a 6-week progressive resistance exercise protocol. Fasting blood glucose, insulin, and their product insulin resistance (HOMA-IR), triglycerides (TRIGS), low density lipoprotein (LDL), high density lipoprotein (HDL), total cholesterol (TC), vascular endothelial growth factor (VEGF), asymmetric dimethylarginine (ADMA), L-arginine (L-ARG) and C-reactive protein (CRP) were established at baseline and following resistance exercise.

**Results:** There were significant improvements in fasting glucose, TC, LDL, HDL and VEGF in both groups following resistance exercise ( $p < 0.05$ , for all). No change was observed in insulin, HOMA-IR, TRIGS, ADMA, L-ARG following resistance exercise ( $p > 0.05$ , in both groups). CRP increased in the South Asian group ( $p < 0.05$ ) but not the Caucasian group ( $p > 0.05$ )





**Conclusions:** The cardio-metabolic response to resistance exercise is comparable in young Caucasian and South Asian males though inflammatory response to exercise may be prolonged in South Asians.


**Keywords**

Resistance, Strength, Exercise, Training, South, Asian, Cardiovascular, Metabolic

**Open Peer Review**

**Reviewer Status**  

	Invited Reviewers	
	1	2
<b>REVISED</b>		
<b>version 2</b>	report	
published		
05 Mar 2019		
		
<b>version 1</b>		
published	report	report
24 Aug 2018		

- Eliza Prodel** , Fluminense Federal University, Niteroi, Brazil
- Majid Ghayour-Mobarhan**, Mashhad University of Medical Science, Mashhad, Iran

Any reports and responses or comments on the article can be found at the end of the article.

**Corresponding author:** Allan Knox ([aknox@callutheran.edu](mailto:aknox@callutheran.edu))

**Author roles:** **Knox A:** Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Software, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Sculthorpe N:** Conceptualization, Data Curation, Formal Analysis, Funding Acquisition, Investigation, Methodology, Project Administration, Resources, Software, Supervision, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Grace F:** Conceptualization, Data Curation, Formal Analysis, Funding Acquisition, Investigation, Methodology, Project Administration, Resources, Software, Supervision, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing

**Competing interests:** No competing interests were disclosed.

**Grant information:** The author(s) declared that no grants were involved in supporting this work.

**Copyright:** © 2019 Knox A *et al.* This is an open access article distributed under the terms of the [Creative Commons Attribution Licence](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

**How to cite this article:** Knox A, Sculthorpe N and Grace F. **Caucasian and south Asian men show equivalent improvements in surrogate biomarkers of cardiovascular and metabolic health following 6-weeks of supervised resistance training [version 2; peer review: 2 approved]** F1000Research 2019, 7:1334 (<https://doi.org/10.12688/f1000research.15376.2>)

**First published:** 24 Aug 2018, 7:1334 (<https://doi.org/10.12688/f1000research.15376.1>)

**REVISED** Amendments from Version 1

There are a few changes in grammar within the new version of the article. Additional information has been added to the 'Participants' and 'Muscular strength and resistance exercise protocol' sections, as requested by reviewers.

See referee reports

## Introduction

Diseases that centre on the cardiovascular (CVD) and glycolytic systems are primary contributors to annual global mortality, accounting for approximately 17.7 million and 1.6 million deaths in 2015, respectively (WHO, 2017a; WHO, 2017b). However, there is considerable heterogeneity of CVD prevalence across racial groups, where the immigrant South Asian (SA) community of the United Kingdom have an approximate 50–100% elevation in cardio-metabolic risk compared with the general population (Wild *et al.*, 2007). This translates to an estimated 5.3 year earlier occurrence of CVD in SAs when compared with their Caucasian (CAUC) counterparts (Hughes *et al.*, 1989).

Pronounced CVD risk amongst SAs is due in part, to the presence of consistently augmented traditional risk factors. For instance, unfavourable lipid profiles have been reported in SAs in comparison to CAUCs (Misra & Khurana, 2011), due to inherent variation of lipid particles. SAs exhibit smaller low density lipoprotein (LDL) particles and dysfunctional high density lipoprotein (HDL) particles compared with CAUCs (Dodani, 2008; Tziomalos *et al.*, 2008). Premature development of Type 2 diabetes (and associated complications) occur approximately 10 years earlier in SAs than CAUCs, and data from large-scale studies such as United Kingdom Asian Diabetes Study (UKADS) reported diabetes related deaths in SAs occurring 7.4 years earlier than CAUCs (Bellary *et al.*, 2010). Comparably higher systemic C-reactive protein (CRP) with regional obesity of the abdomen is another aspect of cardio-metabolic disease that contrives to increase CVD in SAs when compared with CAUCs. The latter has required revisions in the 'normal' BMI thresholds for overweight and obese SAs (Gray *et al.*, 2011). These racially specific reclassifications are based on data demonstrating that comparable levels of glycaemia and lipid profiles are seen at BMI levels of 21–26 kg/m<sup>2</sup> in SAs compared to 30 kg/m<sup>2</sup> in CAUCs (Gray *et al.*, 2011).

Physical exercise is a well-known prophylactic for the development of CVD. In this respect, the cardio protective effects of aerobic exercise are well documented in comparison to fewer studies of resistance exercise (RES). RES has been shown to promote healthogenic effects by improving lipid profiles (Kelley & Kelley, 2009; Sheikholeslami Vatani *et al.*, 2011), insulin sensitivity (Mann *et al.*, 2014; Schwingshackl *et al.*, 2014), and CRP levels (Donges *et al.*, 2010). However, these studies almost exclusively enrol CAUC participants with the result that there is a general paucity of RES studies and resultant data amongst the SA population.

Few investigations have included SA participants and have used lifestyle modification methodologies which have produced

modest results. For instance, a 3-year lifestyle intervention, promoting beneficial dietary and physical activity behaviours in SAs report trivial effects in body mass and no change in either blood pressure or fasting blood glucose (Bhopal *et al.*, 2014). Other investigations that have studied the interaction between physical activity and cardio-metabolic risk in SAs have also found encouraging results. Data from the Health Survey of England show an inverse association between the participation of 30 minutes of moderate intensity exercise per week and cardio-metabolic risk in CAUCs and SAs (Williams *et al.*, 2011). However, findings from the Indian Diabetes Prevention Programme and the ADDITION-Leicester study identified a blunted response in cardio-metabolic biomarkers to physical activity in the SA cohort compared with CAUCs (Yates *et al.*, 2010), which corroborates the findings from other racial comparison studies (Fretts *et al.*, 2009; Steinbrecher *et al.*, 2012). Recently, Iliodromiti and colleagues (2016) have made a valuable addition to the literature by offering that SAs would require ~50% greater participation in physical activity than CAUCs (232 min/week<sup>-1</sup> vs 150 min/week<sup>-1</sup> in CAUCs) to address the imbalance in healthogenic benefits of aerobic exercise between these racial groups.

While these data may have potentially important consequences for exercise prescription for SAs, the field is limited by the dearth of objective assessment of exercise participation. Our previous work has demonstrated differences in muscular strength adaptation in response to supervised RES in SAs, which may translate to an attenuated cardio-metabolic response (Knox *et al.*, 2017). These findings are in line with two previous studies which compared objectively determined physical activity (Iliodromiti *et al.*, 2016) and aerobic exercise (Hall *et al.*, 2010) which support the potential for a blunted response to physical activity in SAs compared with CAUCs. However, no study has explored this phenomenon using the medium RES. Therefore, the purpose of this study was to assess whether the different response of exercise in the SA population suggested by previous reports is applicable to RES. We will address this aim by establishing the response of traditional cardio-metabolic biomarkers to 6-weeks progressive RES between young, healthy CAUC and SA males. We hypothesised that 1) differences in biomarkers of cardio-metabolic health are evident at baseline (PRE) between CAUCs and SAs, 2) differences in biochemical markers in both groups following RES (POST), 3) both groups differ at POST in any biochemical marker of cardio-metabolic health.

## Methods

### Participants

This study was carried out in accordance with the recommendations of the University of the West of Scotland. The protocol was approved by the School of Science and Sport ethics committee (approval: HREC\_Sci2013/02/Knox). All subjects gave written informed consent in accordance with the Declaration of Helsinki. In the present study, the main outcome measure was squat performance. All participants were recruited by local advertisement and word of mouth. Inclusion criteria were that (i) participants did not engage in any recreational or competitive sports, (ii) were naive to RES prior to study enrolment, (iii) no history of cardio-metabolic disease prior to study participation (iv) or any

illness that may provide a contraindication to exercise participation. Only male participants were recruited to control for the effect of sex on potential responses. Race and familial generation of United Kingdom (UK) patriotism was self-reported.

### Anthropometrics

All anthropometric measurements were performed by AK in the Human Performance Laboratory of the University of the West of Scotland (HPLUWS). Height was determined using a portable stadiometer (Leicester Height Measure, Seca, Birmingham, U.K.). Body mass was measured to the nearest 0.1 kg using commercially available scales (TBF-300, Tanita, Tokyo, Japan), where participants were required to remove footwear and unnecessary clothing before measurement which were obtained in adherence with manufacturers guidelines. Body mass index was calculated using the following formula;  $BMI = \text{body mass (kg)} \div \text{height (m)}^2$ . Total body fat percentage (%) was calculated using bioelectrical impedance analysis (BIA) using a commercially available analyser (body composition analyser TBF-300, Tanita, Tokyo, Japan). Criterion validity of this method has been suitably comparable ( $r = 0.952$ ) compared with the gold standard dual energy x-ray absorptiometry (DEXA) (Bozkirli *et al.*, 2007).

Waist circumference (WC) and waist-hip ratio (WHR) was calculated according to the guideline published by the WHO (WHO, 2008) using a commercially available ergonomic circumference measuring tape (Seca 201, Seca, Birmingham). Participants were asked to remove any clothing on their upper body before standing with their arms by their side with their feet positioned close together with their body weight distributed evenly across both feet. For WC, the tape was placed around the approximate midpoint between the lower palpable rib and the top of the iliac crest (WHO, 2008). The participant was then asked to relax and take several deep breaths to account for any abdominal tension caused by the nature of this procedure where criterion measurement was taken at the end of normal expiration to control for any diaphragm movements. Hip circumference (HC) was calculated by measuring the circumference of the widest portion of the buttocks.

### Systemic blood pressure

Systemic blood pressure data was collected by AK in the HPLUWS. Arterial blood pressure (BP) was measured by an automated BP monitor (M6, Omron, Milton Keynes, U.K.). Participants sat in a quiet room for 10 minutes with their legs uncrossed and with the arm being used for measurement supported approximately level with the heart. A total of 3 readings of systolic blood pressure (SBP) and diastolic blood pressure (DBP) were recorded. The final data was calculated from the mean values of the three reading. From these values, it was possible to calculate mean arterial pressure (MAP) the following formula;  $MAP = 0.33(SBP-DBP) + DBP$ .

### Blood biochemistry

All blood sampling and analysis was performed by AK in the HPLUWS. To account for diurnal variation in blood variables, participant blood was sampled at the same time of day and

following a 12-hour fast. Briefly, each participant remained in the supine position for at least 30 minutes during sample collection enabling control of plasma volume shifts (Hagan *et al.*, 1978). Venous blood was collected from the antecubital vein via venepuncture. Blood glucose, triglycerides (TRIGS), HDL and total cholesterol (TC) were determined by spectrophotometry (Rx Monza, Randox Laboratories, UK). Samples were mixed with respective reagents and incubated at room temperature for the duration stated by reagent manufacturer (Randox Laboratories, UK) before being inserted into the spectrophotometer and read at the corresponding wavelength. LDL concentrations were established indirectly by the following Friedewald equation (Friedewald *et al.*, 1972);  $LDL = TC - HDL - (TRIGS/5)$ . This method was appropriate as all samples did not exceed fasting TRIGS concentrations of 4.52 mmol/L and were free from chylomicrons and hyperlipidaemia. Insulin (Alpco Diagnostics Salem, USA: catalogue number: 80-INSHU-E01.1), vascular endothelial growth factor (VEGF: Invitrogen, Life Technologies, USA: catalogue number: BMS277-2), asymmetric dimethylarginine (ADMA) and L-arginine (Diagnostika GMBH, Hamburg, Germany: catalogue number: EA207/192) concentrations were established using commercially available ELISA kits. CRP was determined by commercially available immunoturbidimetric assay (Rx Monza, Randox laboratories, UK: catalogue number: CP3885). Insulin resistance was calculated from the standard formula:  $(\text{fasting glucose} \times \text{fasting insulin})/22.5$ . A small subsample ( $n=6$  from both groups) was used to establish changes in ADMA and L-arginine for hypothesis generating purposes.

### Muscular strength and resistance exercise protocol

Muscular strength assessments were performed by AK in the HPLUWS. All training sessions were performed in local authority fitness centres under the supervision of AK. Measurement of muscular strength, prescribed training protocol, and associated data has been previously reported (Knox *et al.*, 2017). Briefly, lower and upper body muscular strength was assessed by the 3 repetition maximum protocol utilizing the squat and bench press exercise, respectively. The protocol utilised 5 main compound exercises including back squats, bench press, deadlifts, shoulder press, and lateral pull down and progressed in a linear approach three times per week. Each exercise was prescribed at 3 sets of 10 repetitions with 2 minutes' rest between sets. The training programme was separated into two sessions; Session A and Session B, with each being performed consecutively throughout the duration of the study. Training days were separated by at least one day but no longer than two days.

### Statistical analysis

Data were analysed using SPSS version 24.0 for Windows. A power calculation was performed using G\*Power V3 with reference to previously published data regarding squat strength in healthy, untrained, young men (MacDonald *et al.*, 2012). A single-tailed within-group comparison revealed a required sample size of 15 per group (alpha set to 0.05 and power at 0.95). Therefore, the presented data should be considered as hypothesis generating. Group and time interactions, main effects of time and simple main effects of time were determined by a mixed model ANOVA with repeated measures and Bonferonni correction. Distribution of

data was confirmed by Shapiro-Wilks' test. Homogeneity of variances were assessed using Levenes' test for homogeneity of variance. Homogeneity of covariance's was established by Box's test of equality covariance matrices. Assumptions were unviolated ( $p > 0.05$ ) unless otherwise stated. When Mauchly's test of Sphericity were violated ( $p < 0.05$ ), a Greenhouse-Geisser estimate was reported. ANOVA are presented as F test [(degrees of freedom, error terms degrees of freedom) F value,  $p$  value, partial eta-squared ( $\eta^2$ )]. *Post-hoc* data are presented as differences in mean ( $M$ ), 95% CI,  $p$  value. A chi-squared test for association was conducted between groups and impaired fasting glucose levels at PRE and POST. Data is presented as group mean + standard deviation (SD). An alpha of  $p < 0.05$  was used to indicate statistical significance.

## Results

### Participants

Thirty-eight males ( $n=19$  CAUCs,  $n=19$  SAs) were screened and deemed eligible for participation and consequently enrolled. All participants completed PRE measures and initiated supervised RES. Eight participants did not perform POST measures due to non-compliance of the protocol ( $n=4$  CAUCs,  $n=4$  SAs) and two had to withdraw due to personal circumstances ( $n=2$  SAs). The final analysis consisted of 15 CAUC ( $25.5 \pm 4.8$  years) and 13 SA ( $25.4 \pm 7.0$  years) participants. Because 2 SAs participants withdrew from the study due to personal reasons (bereavement), we elected not to conduct an *intention to treat* analysis (See [Figure 1](#)).

### Anthropometrics and systemic blood pressure (mmHg)

No significant group  $\times$  time interactions were observed following RES for; height, BM, BMI, %BF, FM, FFM, WC, HC, WHR ( $p > 0.05$  for all). No statistically significant main effects

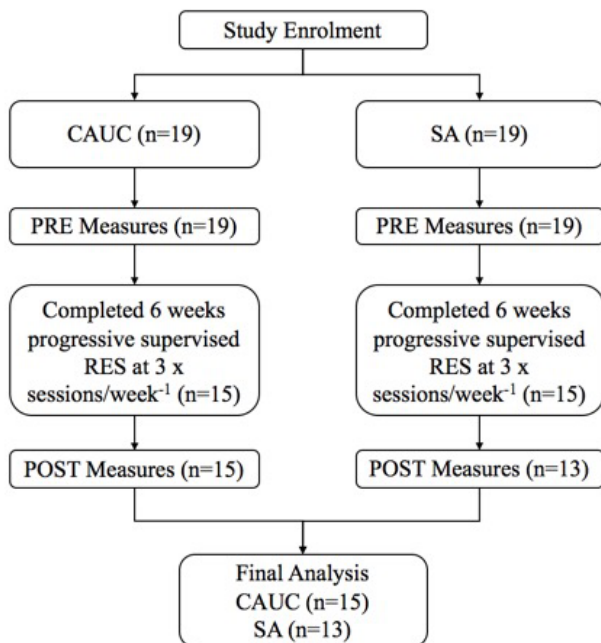
of time following RES were identified in any anthropometric measurement ( $p > 0.05$ ). A simple main effect of time for HC was detected in the CAUC group ( $f_{(1, 24)} = 4.38$ ,  $p = 0.047$ ,  $\eta^2 = 0.15$ ) with a significant decrease from PRE-to-POST ( $M = 3.62$  cm, 95% CI: 0.52 – 7.18,  $p = 0.047$ ). No significant main or simple effects of group were observed in any anthropometric measure apart from WHR, where there was a significant main effect of group ( $f_{(1, 24)} = 5.46$ ,  $p = 0.028$ ,  $\eta^2 = 0.19$ ). The CAUC group presented with a significantly higher WHR at PRE ( $M = 0.52$ , 95% CI: 0.002 – 0.102,  $p = 0.041$ ) and POST ( $M = 0.057$ , 95% CI: 0.006 – 0.107,  $p = 0.029$ ). (See [Table 1](#)).

No group  $\times$  time interaction ( $f_{(1, 25)} = 0.327$ ,  $p = 0.572$ ,  $\eta^2 = 0.01$ ), main effects of time ( $f_{(1, 25)} = 0.002$ ,  $p = 0.96$ ,  $\eta^2 = 0.01$ ) or main effects of group were observed ( $f_{(1, 25)} = 0.01$ ,  $p = 0.909$ ,  $\eta^2 = 0.001$ ) in SBP following RES. SBP did not change within the CAUC ( $M = 1.04$  mmHg, 95% CI: -4.63 – 6.69,  $p = 0.710$ ) or SA groups ( $M = 1.23$  mmHg, 95% CI: -4.64 – 7.11,  $p = 0.670$ ) following RES and both groups were similar at PRE ( $M = 1.49$  mmHg, 95% CI: -5.15 – 7.14,  $p = 0.724$ ) and POST ( $M = 0.76$  mmHg, 95% CI: -5.81 – 7.35,  $p = 0.812$ ) RES. There was a group  $\times$  time interaction in DBP following RES ( $f_{(1, 25)} = 5.95$ ,  $p = 0.022$ ,  $\eta^2 = 0.20$ ). No main effects of time ( $f_{(1, 25)} = 0.83$ ,  $p = 0.373$ ,  $\eta^2 = 0.03$ ), or main effects of group ( $f_{(1, 25)} = 0.04$ ,  $p = 0.85$ ,  $\eta^2 = 0.001$ ) were evident in DBP following RES. The CAUC group reduced DBP ( $M = 5.39$  mmHg, 95% CI: 0.69 – 10.08 mmHg,  $p = 0.026$ ), with no difference in the SA group ( $M = 2.46$  mmHg, 95% CI: -2.23 – 7.16 mmHg,  $p = 0.290$ ). Both groups were similar at PRE ( $M = 3.39$  mmHg, 95% CI: -2.72 – 9.49 mmHg,  $p = 0.264$ ) and POST ( $M = 4.46$  mmHg, 95% CI: -2.93 – 11.85 mmHg,  $p = 0.225$ ).

A trend was seen for a group  $\times$  time interaction ( $f_{(1, 25)} = 3.03$ ,  $p = 0.094$ ,  $\eta^2 = 0.11$ ) in MAP following RES. No main effects of time ( $f_{(1, 25)} = 0.14$ ,  $p = 0.72$ ,  $\eta^2 = 0.01$ ) or main effects of group ( $f_{(1, 25)} = 0.17$ ,  $p = 0.687$ ,  $\eta^2 = 0.01$ ) was seen in MAP following RES. No change was seen in the CAUC ( $M = 3.21$  mmHg, 95% CI: 1.14 – 7.57 mmHg,  $p = 0.141$ ) or SA ( $M = 2.09$  mmHg, 95% CI: 1.43 – 6.61 mmHg,  $p = 0.349$ ) group and both groups were similar at PRE ( $M = 1.47$  mmHg, 95% CI: -5.33 – 8.27 mmHg,  $p = 0.660$ ) and POST ( $M = 3.84$  mmHg, 95% CI: 2.88 – 10.55 mmHg,  $p = 0.250$ ).

### Blood biochemistry

No group  $\times$  time interactions were observed in any variable following RES ( $p > 0.05$  for all comparisons). There was a main effect of time in glucose ( $f_{(1, 16)} = 10.16$ ,  $p = 0.006$ ,  $\eta^2 = 0.39$ ), TC ( $f_{(1, 21)} = 23.12$ ,  $p = < 0.001$ ,  $\eta^2 = 0.52$ ), HDL ( $f_{(1, 17)} = 30.42$ ,  $p = < 0.001$ ,  $\eta^2 = 0.64$ ), LDL ( $f_{(1, 16)} = 40.39$ ,  $p = < 0.001$ ,  $\eta^2 = 0.72$ ) and VEGF ( $f_{(1, 14)} = 12.74$ ,  $p = 0.003$ ,  $\eta^2 = 0.48$ ) following RES. Amongst the CAUC group, there were significant reductions in fasting blood glucose ( $M = 0.77$  mmol/L, 95% CI: 0.03 – 1.51 mmol/L,  $p = 0.041$ ), TC ( $M = 42.09$  mg/dL, 95% CI: 11.26 – 72.92 mg/dL,  $p = 0.010$ ) and LDL ( $M = 47.84$  mg/dL, 95% CI: 24.44 – 71.23 mg/dL,  $p = 0.001$ ), improvements in HDL ( $M = 10.335$  mg/dL, 95% CI: 5.49 – 15.17 mg/dL,  $p = < 0.001$ ) and VEGF ( $M = 33.51$  pg/ml, 95% CI: 6.62 – 60.41 mg/dL,  $p = 0.018$ ) concentrations (see [Figure 2](#)). SA



**Figure 1.** Flow of participants through the study protocol.

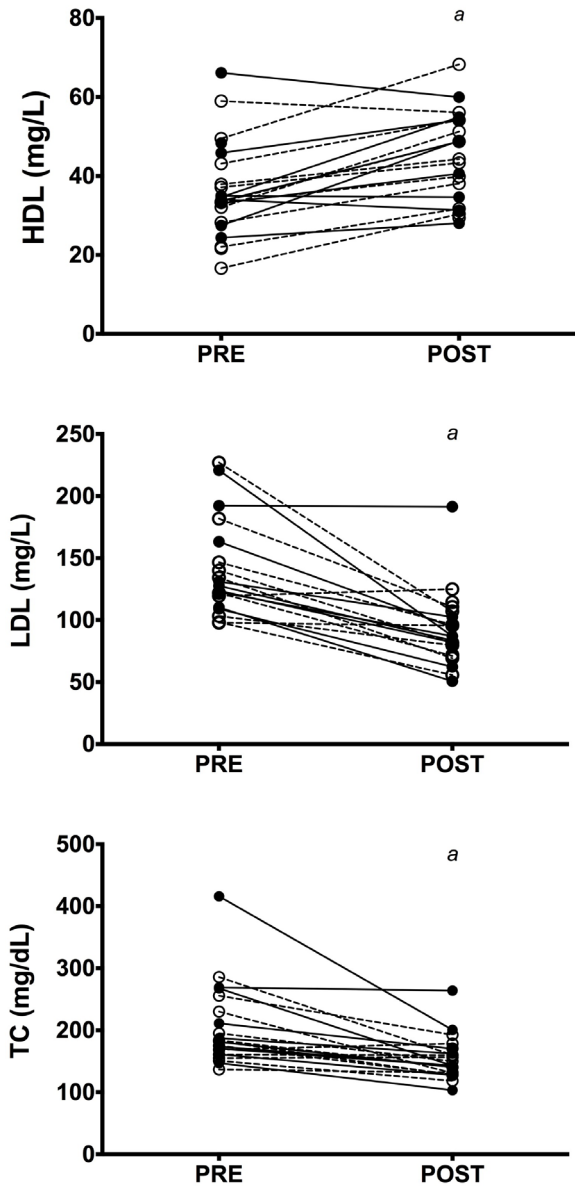
**Table 1. Descriptive statistics of all variables.** Data are presented as group mean  $\pm$  SD. **a** -  $p < 0.05$  from baseline. **b** -  $p < 0.05$  between groups at corresponding time point. Abbreviations: BM – body mass (kg), BMI – body mass index (kg/m<sup>2</sup>), FM – fat mass (kg), FFM – fat free mass (kg), SBP – systolic blood pressure (mmHg), DBP – diastolic blood pressure (mmHg), MAP – mean arterial pressure (mmHg), HOMA-IR – insulin resistance, HDL – high density lipoprotein (mg/dL), LDL – low density lipoprotein (mg/dL), TC – total cholesterol (mg/dL), TRIGS – triglycerides (mg/dL), VEGF – vascular endothelial growth factor (pg/ml), ADMA – asymmetric dimethylarginine ( $\mu$ mol/L), L-ARG – L-arginine ( $\mu$ mol/L), CRP – C-reactive protein (mg/L), CAUC – Caucasian, SA – South Asian, PRE – baseline, POST – following resistance training intervention.

	CAUC		SA		ANOVA Main Effects		
	PRE	POST	PRE	POST	Interaction (p)	Time (p)	Group (p)
<b>Anthropometrics</b>							
Height (cm)	176.73 $\pm$ 5.98	176.70 $\pm$ 4.97	179.69 $\pm$ 7.80	179.88 $\pm$ 8.27	0.794	0.854	0.237
BM (kg)	81.70 $\pm$ 19.70	82.40 $\pm$ 19.85	81.96 $\pm$ 18.57	83.03 $\pm$ 16.62	0.817	0.28	0.951
BMI (kg/m <sup>2</sup> )	25.97 $\pm$ 5.42	26.26 $\pm$ 5.71	25.16 $\pm$ 4.19	25.46 $\pm$ 3.54	0.976	0.220	0.664
Body fat (%)	21.65 $\pm$ 1.85	22.01 $\pm$ 2.11	21.37 $\pm$ 2.01	21.66 $\pm$ 2.36	0.917	0.42	0.914
FM (kg)	19.26 $\pm$ 2.63	19.74 $\pm$ 2.88	18.71 $\pm$ 2.94	18.93 $\pm$ 3.22	0.75	0.408	0.869
FFM (kg)	63.17 $\pm$ 9.19	62.66 $\pm$ 8.41	65.36 $\pm$ 10.02	63.61 $\pm$ 8.01	0.461	0.184	0.644
WC (cm)	90.69 $\pm$ 14.04	87.84 $\pm$ 16.93	85.46 $\pm$ 9.59	83.76 $\pm$ 9.58	0.641	0.076	0.353
HC (cm)	106.69 $\pm$ 9.78	<b>103.08 <math>\pm</math> 13.21<sup>a</sup></b>	107.46 $\pm$ 6.84	106.08 $\pm$ 7.77	0.370	0.052	0.606
WHR	0.85 $\pm$ 0.07	0.85 $\pm$ 0.07	0.79 $\pm$ 0.06	0.79 $\pm$ 0.05	0.739	0.739	0.028
<b>Blood pressure</b>							
SBP (mmHg)	129.04 $\pm$ 10.96	128.0 $\pm$ 8.88	127.53 $\pm$ 10.82	128.77 $\pm$ 7.62	0.572	0.961	0.909
DBP (mmHg)	79.0 $\pm$ 6.14	<b>73.61 <math>\pm</math> 8.66<sup>a</sup></b>	75.62 $\pm$ 8.72	78.08 $\pm$ 9.58	0.022	0.373	0.852
MAP (mmHg)	92.66 $\pm$ 8.23	89.45 $\pm$ 8.21	91.19 $\pm$ 8.87	93.28 $\pm$ 8.72	0.094	0.717	0.687
<b>Muscular Strength</b>							
Lower body (kg)	73.66 $\pm$ 16.65	<b>135.0 <math>\pm</math> 27.71<sup>a</sup></b>	68.84 $\pm$ 16.47	<b>111.53 <math>\pm</math> 16.88<sup>a,b</sup></b>	0.002	<0.001	0.06
Upper body (kg)	51.66 $\pm$ 16.97	<b>65.33 <math>\pm</math> 15.05<sup>a</sup></b>	53.84 $\pm$ 15.43	<b>65.76 <math>\pm</math> 14.26<sup>a</sup></b>	0.476	<0.001	0.822
<b>Blood Biochemistry</b>							
Glucose (mmol/L)	6.05 $\pm$ 1.13	<b>5.28 <math>\pm</math> 0.93<sup>a</sup></b>	6.02 $\pm$ 0.63	<b>5.22 <math>\pm</math> 1.14<sup>a</sup></b>	0.96	0.006	0.912
Insulin ( $\mu$ U/ml)	2.83 $\pm$ 1.98	3.06 $\pm$ 1.98	3.94 $\pm$ 2.07	3.50 $\pm$ 2.34	0.549	0.849	0.383
HOMA-IR	0.69 $\pm$ 0.42	0.60 $\pm$ 0.42	1.20 $\pm$ 0.70	1.16 $\pm$ 0.78	0.826	0.614	0.067
HDL (mg/dL)	35.66 $\pm$ 11.93	<b>46.00 <math>\pm</math> 11.21<sup>a</sup></b>	33.50 $\pm$ 6.28	<b>42.66 <math>\pm</math> 10.48<sup>a</sup></b>	0.744	<0.001	0.551
LDL (mg/dL)	137.01 $\pm$ 40.72	<b>89.17 <math>\pm</math> 21.45<sup>a</sup></b>	138.54 $\pm$ 37.22	<b>81.16 <math>\pm</math> 16.86<sup>a</sup></b>	0.572	<0.001	0.793
TC (mg/dL)	189.91 $\pm$ 45.01	<b>147.82 <math>\pm</math> 22.48<sup>a</sup></b>	231.88 $\pm$ 88.96	<b>170.90 <math>\pm</math> 56.59<sup>a</sup></b>	0.388	<0.001	0.145
TRIGS (mg/dL)	93.27 $\pm$ 36.66	87.20 $\pm$ 34.39	84.35 $\pm$ 42.32	104.22 $\pm$ 72.75	0.156	0.442	0.826
VEGF (pg/ml)	36.86 $\pm$ 26.28	<b>70.39 <math>\pm</math> 49.91<sup>a</sup></b>	44.86 $\pm$ 27.21	<b>74.65 <math>\pm</math> 29.64<sup>a</sup></b>	0.836	0.003	0.687
ADMA ( $\mu$ mol/L)	0.38 $\pm$ 0.09	0.38 $\pm$ 0.43	0.32 $\pm$ 0.12	0.34 $\pm$ 0.07	0.667	0.558	0.314
L-ARG ( $\mu$ mol/L)	62.51 $\pm$ 10.60	66.49 $\pm$ 14.29	71.43 $\pm$ 33.90	62.44 $\pm$ 12.10	0.341	0.707	0.805
CRP (mg/L)	5.40 $\pm$ 2.69	5.89 $\pm$ 3.26	5.96 $\pm$ 3.58	<b>9.50 <math>\pm</math> 2.64<sup>a,b</sup></b>	0.153	0.065	0.093

participants enjoyed comparable improvements in fasting blood glucose ( $M = 0.79$  mmol/L, 95% CI: 0.06 – 1.53 mmol/L,  $p = 0.036$ ) TC ( $M = 60.98$  mg/dL, 95% CI: 28.77 – 93.18 mg/dL,  $p = 0.001$ ) and LDL ( $M = 57.38$  mg/dL, 95% CI: 31.22 – 83.53 mg/dL,  $p = <0.001$ ) and increases in HDL ( $M = 9.16$  mg/dL, 95% CI: 3.49 – 14.83 mg/dL,  $p = 0.003$ ), VEGF ( $M = 29.77$  pg/ml, 95% CI: 2.88 – 56.68 pg/ml,  $p = 0.032$ ) and CRP ( $M = 3.54$  mg/L,

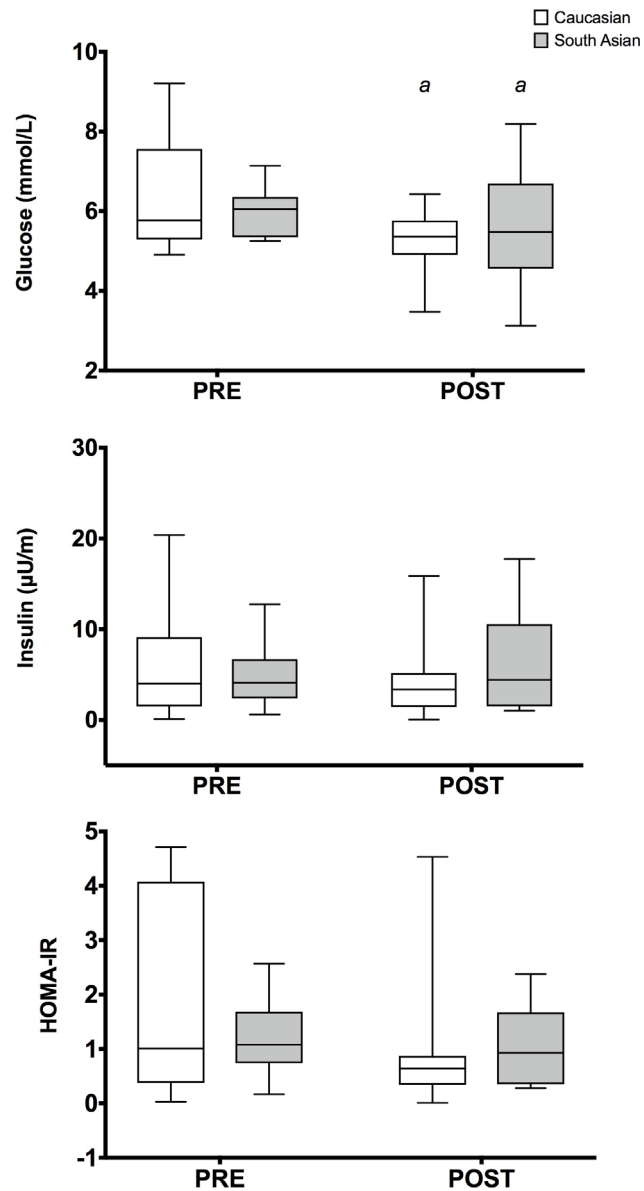
95% CI: 0.07 – 7.01 mg/L,  $p = 0.046$ ). **Figure 3** shows the metabolic response of both groups.

No main effects of group were seen in any biochemical marker ( $p > 0.05$  for all). A trend was observed for a main effect of group on IR ( $f_{(1,15)} = 3.91$ ,  $p = 0.067$ ,  $\eta^2 = 0.207$ ) and CRP ( $f_{(1,15)} = 3.22$ ,  $p = 0.093$ ,  $\eta^2 = 0.177$ ). Both groups were similar at PRE for



**Figure 2. Lipid response to resistance exercise.** Both groups presented favourable lipid responses following resistance exercise. *a* –  $p < 0.05$  from baseline. HDL – high density lipoprotein (mg/dL), LDL – low density lipoprotein (mg/dL), TC – total cholesterol (mg/dL)

glucose ( $M = 0.03$  mmol/L, 95% CI:  $-0.88 - 0.95$  mmol/L,  $p = 0.943$ ), insulin ( $M = 1.11$  U/ml, 95% CI:  $-1.01 - 3.23$  U/ml,  $p = 0.281$ ), TC ( $M = 41.97$  mg/dL, 95% CI:  $-18.38 - 102.32$  U/ml,  $p = 0.163$ ), HDL ( $M = 2.17$  mg/dL, 95% CI:  $-7.64 - 11.96$  mg/dL,  $p = 0.647$ ), LDL ( $M = 1.53$  mg/dL, 95% CI:  $-37.92 - 40.97$  mg/dL,  $p = 0.936$ ), TRIGS ( $M = 8.92$  mg/dL, 95% CI:  $-25.34 - 43.18$  mg/dL,  $p = 0.594$ ), VEGF ( $M = 7.99$  pg/ml, 95% CI:  $-20.69 - 36.68$  pg/ml,  $p = 0.560$ ), L-ARG ( $M = 8.92$   $\mu$ mol/L, 95% CI:  $-23.39 - 41.24$   $\mu$ mol/L,  $p = 0.552$ ), ADMA ( $M = 0.06$   $\mu$ mol/L, 95% CI:  $-0.09 - 0.20$   $\mu$ mol/L,  $p = 0.376$ ) and CRP



**Figure 3. Metabolic response to resistance exercise.** Glucose concentrations were significantly lower in both groups following resistance exercise. *a* –  $p < 0.05$  from baseline. HOMA-IR – insulin resistance.

( $M = 0.57$  mg/L, 95% CI:  $-2.69 - 3.83$  mg/L,  $p = 0.717$ ). A trend was seen at PRE for IR between groups ( $M = 0.51$ , 95% CI:  $-0.10 - 1.12$ ,  $p = 0.096$ ).

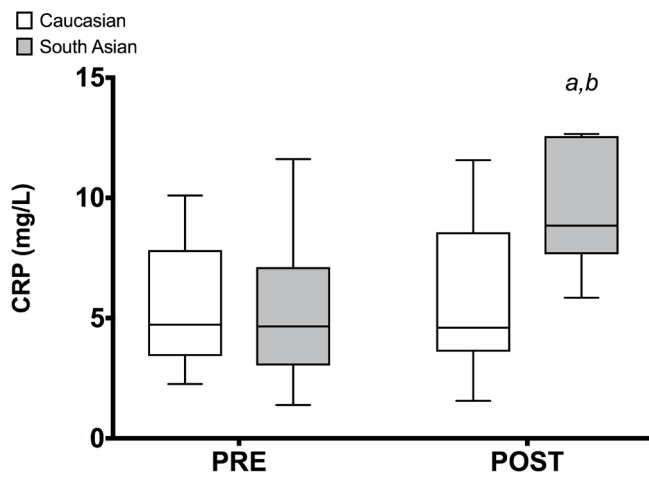
At POST, both groups were comparable for glucose ( $M = 0.06$  mmol/L, 95% CI:  $-0.98 - 1.10$  mmol/L,  $p = 0.910$ ), insulin ( $M = 0.45$   $\mu$ mol/L, 95% CI:  $-1.79 - 2.69$   $\mu$ mol/L,  $p = 0.676$ ), TC ( $M = 23.09$  mg/dL, 95% CI:  $-13.64 - 59.81$  mg/dL,  $p = 0.205$ ), HDL ( $M = 3.34$  mg/dL, 95% CI:  $-7.36 - 14.05$  mg/dL,  $p = 0.519$ ), LDL ( $M = 8.01$  mg/dL, 95% CI:  $-11.67 - 27.69$  mg/dL,



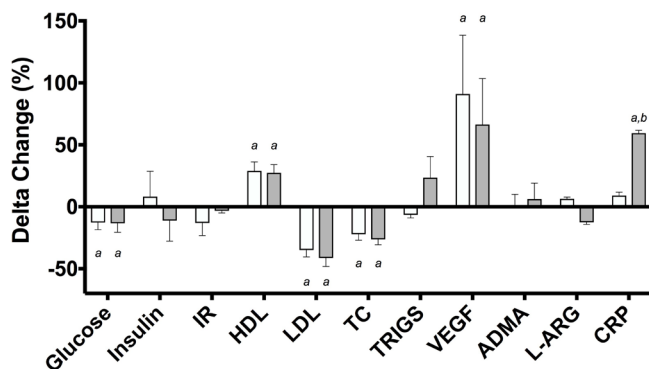
$p = 0.401$ ), TRIGS ( $M = 17.02$  mg/dL, 95% CI:  $-31.62 - 65.66$  mg/dL,  $p = 0.475$ ), VEGF ( $M = 4.28$  pg/ml, 95% CI:  $-39.76 - 48.28$  pg/ml,  $p = 0.839$ ), L-ARG ( $M = 4.05$   $\mu$ mol/L, 95% CI:  $-12.96 - 21.07$   $\mu$ mol/L,  $p = 0.608$ ), ADMA ( $M = 0.04$   $\mu$ mol/L, 95% CI:  $-0.04 - 0.12$   $\mu$ mol/L,  $p = 0.317$ ) with a trend evident for IR ( $M = 0.55$ , 95% CI:  $-0.10 - 1.22$ ,  $p = 0.090$ ). The SA group presented higher CRP levels at POST ( $M = 3.61$  mg/L, 95% CI:  $0.29 - 6.93$  mg/L,  $p = 0.035$ , see Figure 4). Figure 5 illustrates the percentage change of biomarkers in both groups.

### Muscular strength

A significant group  $\times$  time interaction was evident for lower body strength ( $f_{(1,26)} = 11.23$ ,  $p = 0.002$ ,  $\eta^2 = 0.30$ ). A main effect



**Figure 4. C-reactive protein (CRP) changes following resistance exercise.** C-reactive protein concentrations increased in South Asians following resistance exercise, with no change observed within the Caucasian group. *a* -  $p < 0.05$  from baseline, *b* -  $p < 0.05$  between groups.



**Figure 5. Delta percentage changes of all biochemical measures.** Data are presented as means  $\pm$  SD. *a* -  $p < 0.05$  within groups. *b* -  $p < 0.05$  between groups. Abbreviations: IR – insulin resistance, HDL – high density lipoprotein (mg/dL), LDL – low density lipoprotein (mg/dL), TC – total cholesterol (mg/dL), TRIGS – triglycerides (mg/dL), VEGF – vascular endothelial growth factor (pg/ml), ADMA – asymmetric dimethylarginine ( $\mu$ mol/L), L-ARG – L-arginine ( $\mu$ mol/L), CRP – C-reactive protein (mg/L).

of time was also observed ( $f_{(1,26)} = 349.64$ ,  $p < 0.001$ ,  $\eta^2 = 0.93$ ). The CAUC ( $M = 61.33$  Kg, 95% CI:  $53.54 - 69.13$  Kg,  $p < 0.001$ ) and SA ( $M = 42.69$  Kg, 95% CI:  $34.32 - 51.06$  Kg,  $p < 0.001$ ) groups significantly improved lower body strength. Both groups presented similar lower body strength at PRE ( $M = 4.82$  Kg, 95% CI:  $-8.21 - 17.85$  Kg,  $p = 0.454$ ) however, the CAUC group demonstrated higher strength at POST than the SA group ( $M = 23.46$  Kg, 95% CI:  $5.28 - 41.65$  Kg,  $p = 0.013$ ).

No group  $\times$  time interaction was observed for upper body strength ( $f_{(1,26)} = 0.52$ ,  $p = 0.476$ ,  $\eta^2 = 0.02$ ). A main effect of time was seen ( $f_{(1,26)} = 112.89$ ,  $p < 0.001$ ,  $\eta^2 = 0.81$ ). The CAUC ( $M = 13.67$  Kg, 95% CI:  $10.29 - 17.04$  Kg,  $p < 0.001$ ) and SA ( $M = 11.92$  Kg, 95% CI:  $8.30 - 15.55$  Kg,  $p < 0.001$ ) both improved upper body strength. Both groups were similar in upper body strength at PRE ( $M = 2.18$  Kg, 95% CI:  $-10.50 - 14.86$  Kg,  $p = 0.727$ ) and POST ( $M = 0.44$  Kg, 95% CI:  $-11.01 - 11.88$  Kg,  $p = 0.94$ ).

### Discussion

The main findings of the current study demonstrate comparable responses of biomarkers of cardio-metabolic health between CAUC and SA males in response to short-term progressive RES. These responses were evident despite significant differences in muscular strength adaptation. Both groups significantly improved lipid profiles, fasting glucose and VEGF following RES. Although, no difference was observed in fasting TRIGS, insulin, L-ARG, ADMA, or IR following RES in any group, with no apparent discrepancy between groups. CRP increased in the SA group following RES with no change evident in CAUCs.

Previous findings have reported that increasing physical activity levels is beneficial for cardio-metabolic risk in SAs (Dhawan & Bray, 1997; Eriksen *et al.*, 2015; Mathews *et al.*, 2007) (Dhawan & Bray, 1997; Eriksen *et al.*, 2015; Mathews *et al.*, 2007). Dhawan & Bray (1997) showed marked differences in physical activity levels between CAUCs and SAs, however increased physical activity was associated with reductions in insulin, BMI, TRIGS, and blood pressure in both groups. Similarly, Mathews *et al.* (2007) reported improvements in body composition, blood pressure, and lipid profiles following the Khush Dil initiative which involved participation in physical activity and nutritional workshops. Data from the SABRE study reported positive associations between physical activity and markers of cardio-metabolic health in SAs (Eriksen *et al.*, 2015). However, conflicting data suggest a blunted response to physical activity in the SAs cohort.

Data from the Indian Diabetes Prevention Programme (Ramachandran *et al.*, 2006) show no change in body mass following diet and physical activity advice in native Indians, although the intervention group did have a significantly lower incidence of diabetes development at year 3 than the controls. The lack of change in physiological markers are in agreement with later data that show no positive associations with increasing levels of physical activity and body composition in SAs (Yates *et al.*, 2010). These data are supported by a more recent intervention which resulted in mixed body composition responses in SAs (Bhopal *et al.*, 2014).

These studies not only have a key limitation of self-reported measures of physical activity, but also provide difficulty in establishing a dose-response relationship between racial groups to an exercise stimulus. The current study, to our knowledge, is the first to demonstrate a comparable cardio-metabolic response to RES between CAUC and SA males. These data provide evidence that RES is an effective method to improve cardio-metabolic health in the high-risk SA population, with no apparent discrepancy in response when compared with CAUCs. Considering previous investigations have reported a blunted response to aerobic exercise in SAs, the current data provides intriguing evidence that RES interventions may prove superior to aerobic exercise to improve cardio-metabolic health in young SAs. Further research is warranted to determine this theory.

The limited exercise response suggested by the results from previous associations of physical activity and cardio-metabolic health in SAs has initiated several comparative studies. [Hall et al. \(2010\)](#) demonstrated that SAs have a reduced capacity to oxidise fat during submaximal aerobic exercise in comparison with age and body composition matched CAUCs. These data suggest the SAs may need to participate in longer durations or higher exercise intensities to elicit the same physiological benefit from exercise. More recent evidence showing a blunted response in SAs from the same research group used age-adjusted regression models to determine the association between moderate intensity physical activity and cardio-metabolic risk ([Iliodromiti et al., 2016](#)). This study reports that middle-aged SA men and women need to participate in 232 min/week<sup>-1</sup> to elicit comparable cardio-metabolic benefits as CAUCs who perform the currently recommended 150 min/week<sup>-1</sup>. Taken these data together, they suggest a blunted response to exercise in the SA cohort. However, the current investigation demonstrates a comparable cardio-metabolic response to RES between young CAUC and SA males. Further study is warranted to establish if the ability to utilise metabolic substrates during RES is varied between racial groups. The lack of RES studies within the SA population provides difficulty to establish a comparison of existing data which potentially can contribute to our understanding of optimal RES prescription. Nevertheless, the current study demonstrates that progressive RES is effective at improving cardio-metabolic health in young CAUCs and SAs. These data also demonstrate the importance of targeting younger SA individuals to reduce the risk of developing cardio-metabolic diseases that older generations have suffered.

CRP has been regarded as an emerging risk factor for the development of cardiovascular diseases that involve systemic inflammation ([Singh et al., 2008](#)). It has been reported that SA males have a 17% higher concentration of CRP than matched CAUC males, with differences seen in individuals as young as 10 years old ([Chambers et al., 2001](#); [Cook et al., 2000](#)). The current literature concerning the effect of RES on circulating CRP levels is mixed. RES has been shown to reduce CRP levels in African American males with no difference observed in White Americans ([Heffernan et al., 2009](#)). These results may have been a consequence of differential baseline values as the African American group presented higher levels of CRP. Additional work has also reported no change in CRP levels following

10 weeks of RES in individuals with metabolic risk factors ([Levinger et al., 2009](#)). The current study is in agreement with previous research as no changes were seen in the CAUC group. The lack of change in CRP levels following RES within the CAUC group may have been a consequence of no statistical change in body composition as there is a correlation between CRP levels and BMI ([Vlachopoulos et al., 2015](#)). However, a significant increase was seen in the SA group. This may suggest that adequate recovery from a training bout may take longer in the SA group. Previous studies have reported abnormal heart rate recovery from a graded exercise test to be positively associated with CRP levels, independent of physical fitness and disease status ([Jae et al., 2007](#)). Although the current data cannot provide evidence on recovery rates, an abnormal recovery from an exercise bout may be present in the SA population. This requires further exploration.

The current findings may have important clinical implications. According to current guidelines ([American Diabetes Association, 2007](#)), both groups demonstrated impaired fasting glucose at baseline. RES resulted in a significant improvement in both groups to normal fasting glucose levels, suggesting that RES protocols similar to that employed in the current study is sufficient to reduce the risk of type 2 diabetes development. The significant improvement in lipid profiles also demonstrates the efficacy of RES in improving cardio-metabolic health in young CAUC and SA males. Both groups demonstrated significant improvements in TC, LDL and HDL concentrations, which may translate to a significant reduction in cardiovascular risk. This is of importance as our previous work has demonstrated differing rates of adaptation to exercise training between CAUCs and SAs ([Knox et al., 2017](#)), which may imply differing rate of adaptation in other physiological markers. However, the current study has demonstrated that this is not evident in biomarkers of cardio-metabolic health.

This study does not come without several limitations. The small sample size of both racial groups may not provide sufficient statistical power to determine differences in the biomarkers that lacked disparity between groups in response to RES. Nevertheless, the current data would suggest that the biomarkers associated with cardio-metabolic health would respond similarly between CAUCs and SAs in response to RES. The small sample size also makes these data difficult to generalise to whole populations. Additionally, as previous literature using self-reported physical activity levels has suggested a blunted response to exercise in the SA population, a larger sample size that includes participants of similar age to existing literature would be necessary for validation. A larger profile of biomarkers would have also been necessary. There is strong evidence of emerging risk factors such as plasminogen activator inhibitor-1, lipoprotein A, homocysteine, tumor necrosis factor A and several adhesion molecules that are all linked with the development of cardiovascular disease. Interestingly, these compounds seem to be more prevalent in SA individuals when compared to CAUCs ([Gupta et al., 2006](#)). Inclusion of these measures would have given greater detail in the efficacy of RES in the prevention of cardiovascular risk between CAUCs and SAs. Future research concerning the SA population and RES should consider these emerging risk factors

to develop the limited knowledge of exercise response within this population.

In conclusion, supervised progressive RES is effective at improving biomarkers of cardio-metabolic health within young CAUC and SA males, with no apparent discrepancy in response to exercise training. SAs significantly increased CRP levels which may indicate a requirement of a longer recovery following exercise. However, this theory has yet to be confirmed. These data provide an evidence base for interventions to target the younger generation of SAs which may assist in the reduction of future cardio-metabolic diseases that has been prevalent in the SA population for decades.

## Data availability

Underlying data for this study is available from *figshare*: Dataset 1. Short-Term Resistance Exercise and Cardiometabolic Health in Caucasian and South Asian Males, <https://doi.org/10.6084/m9.figshare.6741731.v1> (Knox *et al.*, 2018)

Data available under CC0 1.0 Universal licence

## Grant information

The author(s) declared that no grants were involved in supporting this work.

## References

- American Diabetes Association: **Diagnosis and classification of diabetes mellitus.** *Diabetes Care.* 2007; **30** Suppl 1: S42–47.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Bellary S, O'Hare JP, Raymond NT, *et al.*: **Premature cardiovascular events and mortality in south Asians with type 2 diabetes in the United Kingdom Asian Diabetes Study - effect of ethnicity on risk.** *Curr Med Res Opin.* 2010; **26**(8): 1873–1879.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Bhopal RS, Douglas A, Wallia S, *et al.*: **Effect of a lifestyle intervention on weight change in south Asian individuals in the UK at high risk of type 2 diabetes: a family-cluster randomised controlled trial.** *Lancet Diabetes Endocrinol.* 2014; **2**(3): 218–227.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Bozkirli E, Ertorer ME, Bakiner O, *et al.*: **The validity of the World Health Organisation's obesity body mass index criteria in a Turkish population: a hospital-based study.** *Asia Pac J Clin Nutr.* 2007; **16**(3): 443–447.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Chambers JC, Eda S, Bassett P, *et al.*: **C-reactive protein, insulin resistance, central obesity, and coronary heart disease risk in Indian Asians from the United Kingdom compared with European whites.** *Circulation.* 2001; **104**(2): 145–150.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Cook DG, Mendall MA, Whincup PH, *et al.*: **C-reactive protein concentration in children: relationship to adiposity and other cardiovascular risk factors.** *Atherosclerosis.* 2000; **149**(1): 139–150.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Dhawan J, Bray CL: **Asian Indians, coronary artery disease, and physical exercise.** *Heart.* 1997; **78**(6): 550–554.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Dodani S: **Excess coronary artery disease risk in South Asian immigrants: can dysfunctional high-density lipoprotein explain increased risk?** *Vasc Health Risk Manag.* 2008; **4**(5): 953–961.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Donges CE, Duffield R, Drinkwater EJ: **Effects of resistance or aerobic exercise training on interleukin-6, C-reactive protein, and body composition.** *Med Sci Sports Exerc.* 2010; **42**(2): 304–313.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Eriksen A, Tillin T, O'Connor L, *et al.*: **The impact of health behaviours on incident cardiovascular disease in Europeans and South Asians—a prospective analysis in the UK SABRE study.** *PLoS One.* 2015; **10**(3): e0117364.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Fretts AM, Howard BV, Kriska AM, *et al.*: **Physical activity and incident diabetes in American Indians: the Strong Heart Study.** *Am J Epidemiol.* 2009; **170**(5): 632–639.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Friedewald WT, Levy RI, Fredrickson DS: **Estimation of the Concentration of Low-Density Lipoprotein Cholesterol in Plasma, Without Use of the Preparative Ultracentrifuge.** *Clin Chem.* 1972; **18**(6): 499–502.  
[PubMed Abstract](#)
- Gray LJ, Yates T, Davies MJ, *et al.*: **Defining obesity cut-off points for migrant South Asians.** *PLoS One.* 2011; **6**(10): e26464.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Gupta M, Singh N, Verma S: **South Asians and cardiovascular risk: what clinicians should know.** *Circulation.* 2006; **113**(25): e924–929.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Hagan RD, Diaz FJ, Horvath SM: **Plasma volume changes with movement to supine and standing positions.** *J Appl Physiol Respir Environ Exerc Physiol.* 1978; **45**(3): 414–417.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Hall LM, Moran CN, Milne GR, *et al.*: **Fat oxidation, fitness and skeletal muscle expression of oxidative/lipid metabolism genes in South Asians: implications for insulin resistance?** *PLoS One.* 2010; **5**(12): e14197.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Heffernan KS, Jae SY, Vieira VJ, *et al.*: **C-reactive protein and cardiac vagal activity following resistance exercise training in young African-American and white men.** *Am J Physiol Regul Integr Comp Physiol.* 2009; **296**(4): R1098–1105.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Hughes LO, Raval U, Raftery EB: **First myocardial infarctions in Asian and white men.** *BMJ.* 1989; **298**(6684): 1345–1350.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Iliodromiti S, Ghouri N, Celis-Morales CA, *et al.*: **Should Physical Activity Recommendations for South Asian Adults Be Ethnicity-Specific? Evidence from a Cross-Sectional Study of South Asian and White European Men and Women.** *PLoS One.* 2016; **11**(8): e0160024.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Jae SY, Ahn ES, Heffernan KS, *et al.*: **Relation of heart rate recovery after exercise to C-reactive protein and white blood cell count.** *Am J Cardiol.* 2007; **99**(5): 707–710.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Kelley GA, Kelley KS: **Impact of progressive resistance training on lipids and lipoproteins in adults: a meta-analysis of randomized controlled trials.** *Prev Med.* 2009; **48**(1): 9–19.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Knox A, Sculthorpe N, Baker JS, *et al.*: **Strength adaptation to squat exercise is different between Caucasian and South Asian novice exercisers.** *Res Sports Med.* 2017; **25**(3): 373–383.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Knox A, Sculthorpe N, Grace F: **Short-Term Resistance Exercise and Cardiometabolic Health in Caucasian and South Asian Males.** *figshare.* Dataset. 2018.  
<http://www.doi.org/10.6084/m9.figshare.6741731.v1>
- Levinger I, Goodman C, Peake J, *et al.*: **Inflammation, hepatic enzymes and resistance training in individuals with metabolic risk factors.** *Diabet Med.* 2009; **26**(3): 220–227.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- MacDonald CJ, Lamont HS, Garner JC: **A comparison of the effects of 6 weeks of traditional resistance training, plyometric training, and complex training on measures of strength and anthropometrics.** *J Strength Cond Res.* 2012; **26**(2): 422–431.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Mann S, Beedie C, Balducci S, *et al.*: **Changes in insulin sensitivity in response to different modalities of exercise: a review of the evidence.** *Diabetes Metab Res Rev.* 2014; **30**(4): 257–268.  
[PubMed Abstract](#) | [Publisher Full Text](#)
- Mathews G, Alexander J, Rahemtulla T, *et al.*: **Impact of a cardiovascular risk control project for South Asians (Khush Dil) on motivation, behaviour, obesity,**

**blood pressure and lipids.** *J Public Health (Oxf)*. 2007; **29**(4): 388–397.

[PubMed Abstract](#) | [Publisher Full Text](#)

Misra A, Khurana L: **Obesity-related non-communicable diseases: South Asians vs White Caucasians.** *Int J Obes (Lond)*. 2011; **35**(2): 167–187.

[PubMed Abstract](#) | [Publisher Full Text](#)

Ramachandran A, Snehalatha C, Mary S, *et al.*: **The Indian Diabetes Prevention Programme shows that lifestyle modification and metformin prevent type 2 diabetes in Asian Indian subjects with impaired glucose tolerance (IDPP-1).** *Diabetologia*. 2006; **49**(2): 289–297.

[PubMed Abstract](#) | [Publisher Full Text](#)

Schwingshackl L, Missbach B, Dias S, *et al.*: **Impact of different training modalities on glycaemic control and blood lipids in patients with type 2 diabetes: a systematic review and network meta-analysis.** *Diabetologia*. 2014; **57**(9): 1789–1797.

[PubMed Abstract](#) | [Publisher Full Text](#)

Sheikholeslami Vatani D, Ahmadi S, Ahmadi Dehrashid K, *et al.*: **Changes in cardiovascular risk factors and inflammatory markers of young, healthy, men after six weeks of moderate or high intensity resistance training.** *J Sports Med Phys Fitness*. 2011; **51**(4): 695–700.

[PubMed Abstract](#)

Singh U, Dasu MR, Yancey PG, *et al.*: **Human C-reactive protein promotes oxidized low density lipoprotein uptake and matrix metalloproteinase-9 release in Wistar rats.** *J Lipid Res*. 2008; **49**(5): 1015–1023.

[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)

Steinbrecher A, Erber E, Grandinetti A, *et al.*: **Physical activity and risk of type 2 diabetes among Native Hawaiians, Japanese Americans, and Caucasians: the Multiethnic Cohort.** *J Phys Act Health*. 2012; **9**(5): 634–641.

[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)

Tziomalos K, Weerasinghe CN, Mikhailidis DP, *et al.*: **Vascular risk factors in**

**South Asians.** *Int J Cardiol*. 2008; **128**(1): 5–16.

[PubMed Abstract](#) | [Publisher Full Text](#)

Vlachopoulos C, Xaplanteris P, Aboyans V, *et al.*: **The role of vascular biomarkers for primary and secondary prevention. A position paper from the European Society of Cardiology Working Group on peripheral circulation: Endorsed by the Association for Research into Arterial Structure and Physiology (ARTERY) Society.** *Atherosclerosis*. 2015; **241**(2): 507–532.

[PubMed Abstract](#) | [Publisher Full Text](#)

WHO: **Waist Circumference and waist-hip ratio: Report of a WHO expert consultation.** (8–11 December 2008 ed.). Geneva: World Health Organisation. 2008.

[Reference Source](#)

WHO: **Cardiovascular Diseases (CVD).** 2017a.

[Reference Source](#)

WHO: **Diabetes.** 2017b.

[Reference Source](#)

Wild SH, Fischbacher C, Brock A, *et al.*: **Mortality from all causes and circulatory disease by country of birth in England and Wales 2001–2003.** *J Public Health (Oxf)*. 2007; **29**(2): 191–198.

[PubMed Abstract](#) | [Publisher Full Text](#)

Williams ED, Stamatakis E, Chandola T, *et al.*: **Physical activity behaviour and coronary heart disease mortality among South Asian people in the UK: an observational longitudinal study.** *Heart*. 2011; **97**(8): 655–659.

[PubMed Abstract](#) | [Publisher Full Text](#)

Yates T, Davies MJ, Gray LJ, *et al.*: **Levels of physical activity and relationship with markers of diabetes and cardiovascular disease risk in 5474 white European and South Asian adults screened for type 2 diabetes.** *Prev Med*. 2010; **51**(3–4): 290–294.

[PubMed Abstract](#) | [Publisher Full Text](#)

# Open Peer Review

Current Peer Review Status:  

---

## Version 2

Reviewer Report 13 March 2019

<https://doi.org/10.5256/f1000research.20179.r45264>

© 2019 Prodel E. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution Licence](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.



**Eliza Prodel** 

Laboratory of Exercise Sciences, Department of Physiology and Pharmacology, Fluminense Federal University, Niteroi, Brazil

The authors have satisfactorily improved the manuscript. Therefore, I now recommend the publication.

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Exercise physiology; cardiology; integrative physiology

**I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.**

---

## Version 1

Reviewer Report 11 December 2018

<https://doi.org/10.5256/f1000research.16755.r41730>

© 2018 Ghayour-Mobarhan M. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution Licence](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.



**Majid Ghayour-Mobarhan**

Cardiovascular Research Center, Mashhad University of Medical Science, Mashhad, Iran

The manuscript by Knox et al., tries to compare the response in biomarkers of cardio-metabolic health in Caucasians and South Asians in response to resistance exercise. The study appears to have been done in a careful and competent manner. I have few comments that require further clarification.

Method part: Why were samples selected from male participants in the study? Please explain more in this regard. While more details of method will provide to allow replication by others.

Results and discussion parts: Also please include other anthropometric indices as CVD risk factors such as the waist circumference-to-hip circumference ratio, ect in the text, if it is possible because it has been proposed to assess central obesity and as measures for cardio-metabolic disorders and events. Therefore, insert and explain the associations them in the result and discussion sections.

**Is the work clearly and accurately presented and does it cite the current literature?**

Yes

**Is the study design appropriate and is the work technically sound?**

Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**

Partly

**If applicable, is the statistical analysis and its interpretation appropriate?**

I cannot comment. A qualified statistician is required.

**Are all the source data underlying the results available to ensure full reproducibility?**

Yes

**Are the conclusions drawn adequately supported by the results?**

Yes

**Competing Interests:** No competing interests were disclosed.

**I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.**

Reviewer Report 21 September 2018

<https://doi.org/10.5256/f1000research.16755.r38063>

© 2018 Prodel E. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution Licence](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.



**Eliza Prodel** 

Laboratory of Exercise Sciences, Department of Physiology and Pharmacology, Fluminense Federal University, Niteroi, Brazil

In the paper entitled “Caucasian and south Asian men show equivalent improvements in surrogate biomarkers of cardiovascular and metabolic health following 6-weeks of supervised resistance training” you had the aim to investigate the cardio-metabolic response to resistance exercise training in South Asian and Caucasian population. The work is well written, and presents very interesting data, however a have a few issues to clarify.

**Major**

The whole introduction is based on the fact that SA's are cardio-metabolic different from CAUCC's, so why you hypothesized no differences would be found in the results?

Why only male participants were enrolled in the study? You would have more complete results and an avenue to discuss if women were tested.

Data of muscular strength gain could be more clear in a table or graph.

It is not mandatory, however I feel that the authors could explore more about cardiovascular data and their relationship with the metabolic data. For example, changing in rest and recovery heart rate and heart rate variability with the RES training.

**Methods**

Participants section:

1. Performance measurements (upper and lower body) should be in a specific section, and would be appropriate to provide more detailed information.
2. "A single-tailed within-group comparison revealed a required sample size of 15 per group (alpha set to 0.05 and power at 0.95). Therefore, the presented data should be considered as hypothesis generating." Should be in statistical analysis section.

**Minor**

Page 5: "Neither was there any change within in the CAUC". Small writing mistake.

Page 8: "however, the CAUC group showed demonstrated higher strength at POST than the SA group". Small writing mistake.

**Is the work clearly and accurately presented and does it cite the current literature?**

Yes

**Is the study design appropriate and is the work technically sound?**

Partly

**Are sufficient details of methods and analysis provided to allow replication by others?**

Partly

**If applicable, is the statistical analysis and its interpretation appropriate?**

Yes

**Are all the source data underlying the results available to ensure full reproducibility?**

No

**Are the conclusions drawn adequately supported by the results?**

Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Exercise physiology; cardiology; integrative physiology

**I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.**

Author Response 26 Feb 2019

**Allan Knox**, Rutgers University, Thousand Oaks, USA

The authors thank you for taking the time to review our manuscript. We have considered all comments and provided our responses below;

Comment: The whole introduction is based on the fact that SA's are cardio-metabolic different from CAUCC's, so why you hypothesized no differences would be found in the results?

Response: We have clarified our hypothesis to reflect the background information that is reported in the introduction of the manuscript.

Comment: Why only male participants were enrolled in the study? You would have more complete results and an avenue to discuss if women were tested.

Response: There is paucity of experimental exercise research in south Asian males and none in south Asian females. We sought to focus on the male population to control for the possibility of an effect of sex in responses to resistance exercise training. We agree that more data is required on exercise responses in south Asian females, something that we wish to explore in a more comprehensive sample in future experimental work.

Comment: Data of muscular strength gain could be more clear in a table or graph.

Response: We thank you and appreciate your comment regarding the request for a graph illustrating muscular strength gains. We feel it is unfeasible to provide additional graphs for strength gains due to the number of muscle groups trained. All data regarding strength gains is presented in tables. In addition, these tables are more informatory presented as means and standard deviations due to the differences in strength response.

Comment: It is not mandatory, however I feel that the authors could explore more about cardiovascular data and their relationship with the metabolic data. For example, changing in rest and recovery heart rate and heart rate variability with the RES training.

Response: We fully appreciate this comment and are considering exploring these data in more detail.

Comment: Performance measurements (upper and lower body) should be in a specific section, and would be appropriate to provide more detailed information.

Response: We are constrained by the word count available to provide additional information regarding the performance measures. We have referenced previous research that has full details of all procedures.

Comment: "A single-tailed within-group comparison revealed a required sample size of 15 per group (alpha set to 0.05 and power at 0.95). Therefore, the presented data should be considered as hypothesis generating." Should be in statistical analysis section.

Response: This has now been moved to the statistical analysis section.



Comment: Page 5: “Neither was there any change within in the CAUC”. Small writing mistake

Response: Amended in manuscript.

Page 8: “however, the CAUC group showed demonstrated higher strength at POST than the SA group”. Small writing mistake.

Response: Amended in manuscript.

**Competing Interests:** No competing interests were disclosed.

The benefits of publishing with F1000Research:

- Your article is published within days, with no editorial bias
- You can publish traditional articles, null/negative results, case reports, data notes and more
- The peer review process is transparent and collaborative
- Your article is indexed in PubMed after passing peer review
- Dedicated customer support at every stage

For pre-submission enquiries, contact [research@f1000.com](mailto:research@f1000.com)

F1000Research