Brief Communication: Cardiorespiratory fitness and fat oxidation during exercise in Chinese, Indian, Malay men with elevated body mass index.

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Running title: Fat oxidation during exercise in overweight Asian men

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Abstract

A cross-sectional pilot investigation in Chinese, Indian and Malay men (15 each) with elevated BMI to compare: (i) cardiorespiratory fitness (CRF); and (ii) fat oxidation at rest and maximal fat oxidation during exercise. Predicted CRF (Chinese: 37.0 (5.1) mL/kg/min; Indian: 34.8 (5.6) mL/kg/min; Malay: 33.0 (7.1) mL/kg/min; $P = 0.208$) and resting fat oxidation were similar among groups. Maximal fat oxidation during exercise was lower in Indian (3.81 (1.02) mg/kg/min, $P = 0.004$) and Malay (Malay: 3.36 (0.95) mg/kg/min, $P < 0.001$) than Chinese (5.17 (1.23) mg/kg/min) men. Fat oxidation during exercise may contribute toward obesity risk in Asian populations.

ClinicalTrials.gov Identifier: NCT05337111

Keywords: cardiorespiratory fitness; fat oxidation; ethnicity; overweight

Introduction

South Asians have lower cardiorespiratory fitness (CRF) than white Europeans (Ghouri et al. 2013; Hall et al. 2010) and this difference presents early in life (Nightingale et al. 2016). In South Asian men, lower CRF persists for any given level of physical activity even after controlling for differences in age, body mass index (BMI) and fat mass (Hall et al. 2010; Ghouri et al. 2013). Low CRF is associated with a reduced capacity to oxidise fat at the whole-body level during exercise, which is a risk factor for weight gain/regain (Dandanell et al. 2017; Maunder et al. 2018). Indeed, fat oxidation is lower at the same relative and absolute sub-maximal exercise intensities in South Asian than white European men even after adjustment for age, BMI and fat mass (Hall et al. 2010). This is despite increased skeletal muscle expression of genes associated with lipid metabolism in South Asians (Hall et al. 2010).

Whilst comparisons with Europeans are valuable, Asians are not a homogenous group. Substantial differences in obesity and body fat partitioning exist with ethnicity (Khoo et al. 2014; Sadnanthan et al. 2019) and the relationship of increased BMI with cardiometabolic outcomes is not uniform among Asian ethnic groups, even within the same country (Ministry of Health Singapore, 2020). Differences in CRF and fat oxidation during exercise potentially contribute to these observations (Hall et al. 2010). One cross-sectional study in Singapore found a greater percentage of Indian and Malay than Chinese women in the lowest category of predicted CRF after a 1-mile walking test (Pua et al. 2006). However, further data to support differences among these major ethnic groups are limited and not available in men. Moreover, it is uncertain if fat oxidation during exercise differs among these ethnic groups. Thus, the present pilot investigation aimed to compare CRF and fat oxidation at rest and maximal fat oxidation during exercise in Chinese, Indian and Malay men (from Singapore) with elevated BMI (23 -30 kg/m^2). Participants in this BMI range were selected to ascertain if CRF and fat oxidation differ among these ethnic groups before progression to obesity (BMI ≥ 30 kg/m^2) occurs. It was hypothesised that Indian and Malay men would have lower predicted CRF and maximal fat oxidation during exercise than their Chinese counterparts.

Materials and Methods

The study was approved by Nanyang Technological University Institutional Review Board (IRB-2018-03-028). The study was retrospectively registered within a public registry (ClinicalTrials.gov Identifier: NCT05337111). Forty-five men of Chinese, Indian and Malay descent (15 of each ethnicity) provided written informed consent. Inclusion criteria were: (i) age 25 - <45 years; (ii) (Han) Chinese, Indian or Malay based on self-identity for three generations (parents and grandparents); (iii) BMI ≥ 23 – < 30 kg/m^2 (WHO Expert Consultation 2004) and/or waist circumference ≥ 90 cm (Alberti et al. 2009); (iv) physically inactive defined as < 150 minutes moderate or < 75 minutes vigorous leisure-time physical activity per week, or the equivalent combination of both (World Health Organization 2010; Armstrong and Bull 2006); (v) no personal history of cardio-metabolic diseases; (vi) not dieting; (vii) non-smoker; (viii) consuming alcohol < 3 times per week with < 3 drinks per time; (ix) not taking medications affecting carbohydrate or lipid metabolism; (x) no lower body injuries; (xi) fasting blood glucose < 6.1 mmol/L.

Participants undertook two laboratory visits after an 8-10 hour overnight fast – water only - on separate mornings at least 72 hours apart. Participants background diet was monitored before each visit and they were asked to maintain normal physical activity habits (considered physically inactive) during the study. For visit one, stature and body mass were measured using standard methods (Seca 764; Seca GmbH & Co. KG., Hamburg, Germany). Waist circumference was measured midway between the inferior margin of the ribs and superior border of the iliac crest using a flexible measuring tape. Body composition was determined via bioimpedance (InBody720; Biospace Co. Ltd., Seoul, Korea). Fasting glucose was measured from a finger-prick blood sample (Accu-Chek; Roche Diagnostics GmbH, Mannheim, Germany). Participants underwent a submaximal exercise test to estimate their CRF (maximal oxygen uptake, $\dot{V}O_2$max) during walking using a modified standard protocol (Balke and Ware 1959). Participants walked on a treadmill at 5 km/h. Initial gradient was 0% and this increased 1% each minute until individuals reach 80% of their estimated maximal heart rate [220 – age (years)] monitored via short-range telemetry (Polar RS400; Polar, Oulu, Finland). Perceived exertion was assessed periodically during the test (Borg 1973). Expired gases were continuously measured via a mouthpiece attached to an automated metabolic cart (Parvomedics MMS-2400; Parvomedics, Sandy, UT) and oxygen consumption extrapolated to estimate $\dot{V}O_2$max based on estimated maximal heart rate.

For visit two, participants spent 30 minutes under a ventilated hood attached to an automated metabolic cart (Parvomedics MMS-2400; Parvomedics, Sandy, UT). Oxygen consumption and carbon dioxide production were calculated via a dilution method to determine resting energy expenditure (REE) and the fraction of energy expenditure contributed by carbohydrate and fat oxidation (Mansell and Macdonald 1990). The first 15 minutes of measurement acted as a habituation period and the last 15 minutes used for data processing (Melby et al. 1993). Participants then underwent an exercise test for the measurement of maximal fat oxidation using a modified standard protocol (Hall et al. 2010). Participants walked on a treadmill starting at 3 km/h. Speed was increased by 1 km/h every 4 minutes until 5 km/h and subsequently gradient by 1% every 4 minutes until the stage RER was ≥ 0.95. Expired air was measured continuously (Parvomedics MMS-2400; Parvomedics, Sandy, UT) and data from the final minute of each stage used to calculate the fraction of energy and the absolute energy expenditure from fat oxidation, assuming no protein oxidation (Kuo et al. 2005). For each individual, we constructed a curve of fat oxidation against exercise intensity across the different stages from which maximal fat oxidation was determined via regression. Reliability of similar treadmill tests to determine maximal fat oxidation during exercise is ~10% (Maunder et al. 2018).

Data were analysed using statistical software (SPSS Version 26.0; IBM Corp, Chicago, IL). Differences in predicted $\dot{V}O_2$max, fat oxidation at rest and maximal fat oxidation during exercise among ethnic groups were compared using one-way ANOVA. Bonferroni adjusted t-tests were used to examine between group differences and are reported along with the 95% confidence intervals (CI) of the differences. Pearson correlation was used to examine associations among body composition, $\dot{V}O_2$max and maximal fat oxidation during exercise. Significance was set at $P < 0.05$.

Results

Table 1 outlines the physical characteristics, predicted CRF, resting energy expenditure and metabolism, and maximal fat oxidation during exercise in the three groups of men. Physical characteristics did not significantly differ, but BMI and body fat percentage showed some tendency toward a difference. Predicted $\dot{V}O_2$max was ~6% and 12% greater in Chinese than their Indian and Malay counterparts, respectively, but not statistically different. Expressing $\dot{V}O_2$max relative to fat free mass (FFM) removed proportional differences between Chinese and Indian – but not Malay – men without changing statistical findings.

The REE, along with the absolute and relative fat and carbohydrate contributions to REE, were similar among groups. However, absolute maximal fat oxidation during exercise was 29% higher in Chinese than Indian (P = 0.042, 95% CI [0.002, 0.170]) and 48% higher in Chinese than Malay (P = 0.002, 95% CI [0.040, 0.208]) men. Differences in fat oxidation remained when expressed relative to body mass (Chinese vs. Indian P = 0.004, 95% CI [0.377, 2.334]; Chinese vs. Malay P < 0.001, 95% CI [0.827, 2.784]) but when expressed relative to FFM were attenuated between Chinese and Indian (P = 0.198, 95% CI [-0.353, 2.560]) but not Malay (P = 0.005, 95% CI [0.505, 3.418]) men. No differences were seen in any indices of maximal fat oxidation during exercise between Indian and Malay men (all P > 0.05). Findings for fat oxidation did not change when adjusted (using ANCOVA) for BMI and body fat percentage or when adjusted for: (i) age, (ii) $\dot{V}O_2max$, (iii) fat mass, (iv) fasting glucose or (v) carbohydrate oxidation at the same intensity (data not shown). Maximal fat oxidation expressed relative to resting fat oxidation was similar between Chinese and Indian men (Chinese: 4.4 (1.1.) vs. Indian: 3.8 (1.1), P = 0.342, 95% CI [-0.329, 1.534]) but differed between Chinese and Malay men (Chinese: 4.4 (1.1.) vs. Malay: 3.8 (1.1), P = 0.012, 95% CI [0.202, 2.065]). The percentage of predicted $\dot{V}O_2max$ at which maximal fat oxidation occurred was lower in Malay than Chinese men (Chinese: 4.4 (1.1.) vs. Malay: 3.8 (1.1), P = 0.026, 95% CI [1.018, 20.45]) but not different between Chinese and Indian or Indian and Malay men.

For Chinese and Indian men only, $\dot{V}O_2max$ was negatively associated with fat mass (Chinese: r = -0.589, P = 0.021; Indian: r = -0.585, P = 0.022) and body fat percentage (Chinese: r = -0.627, P = 0.012; Indian: r = -0.592, P = 0.020), and to some extent waist circumference

(Chinese: r = -0.492, P = 0.063; Indian: r = -0.599, P = 0.018). In Malay men only, $\dot{V}O_2max$ expressed relative to FFM was associated with absolute maximal fat oxidation during exercise (r = 0.545, P = 0.036). Body composition measures did not correlate with maximal fat oxidation during exercise in any group (data not shown).

Discussion

Chinese men with elevated BMI exhibit higher maximal fat oxidation during exercise than their Indian or Malay counterparts. Whilst CRF is closely associated with the skeletal muscle capacity to oxidise fat and is lower in individuals of South Asian compared with white European descent (Hall et al. 2010) it did not differ by ethnicity in our study. Moreover, correcting for $\dot{V}O_2max$ did not attenuate differences in maximal fat oxidation observed among groups suggesting that other factors are involved.

Unlike studies comparing white and South Asian men (Ghouri et al. 2013; Hall et al. 2010), there was no significant difference in CRF among Asian ethnic groups here, despite $\dot{V}O_2max$ being proportionally higher in Chinese than Indian and Malay men. Use of a predicted $\dot{V}O_2max$ test may have masked differences in CRF among groups and is a study limitation. However, the proportional difference in CRF was also negated between Chinese and Indian men after correcting for FFM. Importantly, CRF was negatively associated with indicators of fat mass (BMI, body fat percentage, waist circumference) in Chinese and Indians, even within the limited BMI range of this small study - as also seen in South Asian women (Lesser et al. 2015). Even though we did not see differences in CRF among ethnic groups here, differences in maximal fat oxidation during exercise were evident. Again, however, differences between Chinese and Indians were attenuated when expressed relative to FFM, even though body composition was not associated with maximal fat oxidation. Moreover, Indians were able to increase their fat oxidation from rest to exercise to the same relative extent as Chinese. Subtle differences in compartmental FFM may explain these observations as Indians have a greater proportion of limb FFM than Chinese (Song et al. 2016) which contributes to fat oxidation during treadmill exercise. Differences in fat oxidation, nonetheless, persisted between Malay and Chinese men even after accounting for body composition (BMI and percentage body fat). The reason for this is uncertain. However, the percentage of predicted $\dot{V}O_2max$ that Malay men achieved maximal fat oxidation was lower than that of Chinese men and at the lower end of percentile values reported in the literature for overweight men (Maunder et al. 2018). Differences in mitochondrial capacity or expression of genes involved in lipid metabolism could be an explanation (Hall et al. 2010). Certainly, CRF relative to FFM was associated with maximal fat oxidation during exercise in Malay men and future studies should examine the role of FFM in fat oxidation in these men further. Finally, these differences in the capacity to oxidise fat during exercise could be a contributor to the much greater prevalence of obesity - and type 2 diabetes - in Indian and Malay men in Singapore compared with their Chinese counterparts (Ministry of Health Singapore, 2020).

There were no differences in REE or fat oxidation among ethnic groups in the present study, perhaps because skeletal muscle only contributes ~20% of total REE and whole-body fat oxidation is determined mostly by other organs (Hall et al. 2010). We accept the possibility of a type 2 error for our resting data which contrast with a previous larger cross-sectional study where REE (fat oxidation not reported) was greater in Chinese (n=100) than Indian (n=70), but not Malay (n=74) men (Song et al. 2016); explained by the fact that Indians have a smaller proportion of truncal FFM and lean tissue as high metabolic rate organs. Nonetheless, that same study did not report differences in resting fat oxidation among ethnic groups (Song et al. 2016). Differences in resting fat oxidation are also not seen in cross-sectional studies comparing age, sex and BMI matched Asians and white individuals (Hall et al. 2010; Wulan et al. 2012). Whilst we are cautious in relation to our own small sample, collectively the data from these various observations suggest resting fat oxidation may not be lower in Indians than other ethnic groups.

The inclusion of men only is a limitation, as evidence suggests that Indian and Malay women may be affected by overweight and obesity to a greater extent than men (Song et al. 2016). As already noted, the use of a predicted $\dot{V}O_2$max test based on estimated maximal heart rate has potential inaccuracies which may mask differences in CRF among groups. Bioimpedance has limitations as a technique for measuring body composition but application of the technique was consistent and standardised, and it has been argued that errors in precision and accuracy with bioimpedance are not necessarily greater than gold-standard techniques (Ward 2019). Finally, we included only Asian men at moderate-to-high risk of diseases associated with elevations in BMI (WHO Expert Consultation 2004). By omitting individuals at lower risk of these diseases, we cannot confirm whether differences in fat oxidation observed occur with elevations in BMI or are pre-existing among these ethnic groups.

In summary, CRF is similar among Chinese, Malay and Indian men from Singapore with elevated BMI but Indian and Malay men have a lower maximal fat oxidation during exercise. For Indian men, differences in FFM appear to partly explain this finding. Prospective studies should examine if reduced fat oxidation during exercise explains ethnic differences in the risk of developing obesity and body fat partitioning among Asians.

Acknowledgements

We thank Mr Muhammad Ibrahim Bin Nasaruddin for his assistance with the data collection and Mr Muhammad Farihin Fawwaz for his assistance in the laboratory.

Competing Interests

The authors declare there are no competing interests.

Author Contributions

Conceptualisation: SFB; funding: SFB, RD; methodology: all authors; formal analysis: MD, SFB; supervision: SFB; writing-original draft: MD, SFB; editing: all authors.

Funding Statement

This research/project was supported by the Ministry of Education, Singapore, under its Academic Research Fund Tier 1 (2017-T1-002-036).

Data Availability Statement

Data related to this publication will be placed in the Data Repository of the Nanyang Technological University National Institute of Education (Singapore) and made available upon reasonable request to the Corresponding Author (SFB).

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Table 1. Physical characteristics, physical activity, cardiorespiratory fitness, resting metabolism and maximal exercise fat oxidation of the men in each ethnic group in the study.

	Chinese (n=15)	Indian (n=15)	Malay (n=15)	P_{ANOVA}
Physical characteristics[a]:				
Age (years)	31.3 (6.2)	28.1 (1.9)	29.3 (5.3)	0.200
Body mass (kg)	76.3 (7.4)	77.5 (9.3)	76.1 (10.2)	0.896
BMI (kg/m^2)	25.1 (1.6)	26.6 (2.0)	26.5 (2.0)	0.063
Waist circumference (cm)	86.3 (5.1)	88.9 (6.8)	86.8 (5.1)	0.410
Body fat (%)	25.8 (5.6)	30.6 (6.3)	27.7 (5.4)	0.089
Fat mass (kg)	19.7 (5.5)	23.9 (6.3)	21.2 (6.0)	0.167
Fat free mass (kg)	56.5 (5.2)	53.4 (7.1)	54.9 (6.6)	0.456
Fasting glucose (mmol/L)	5.53 (0.30)	5.65 (0.22)	5.65 (0.24)	0.319
Physical activity[a]:				
Sedentary time (mins/day)	670 (220)	674 (182)	708 (214)	0.858
LT-MVPA (MET-mins/wk)	271 (240)	271 (234)	197 (247)	0.631
Cardiorespiratory fitness[a]:				
$\dot{V}O_2$max (mL/kg/min)	37.0 (5.1)	34.8 (5.6)	33.0 (7.1)	0.194
$\dot{V}O_2$max (mL/kgFFM/min)	49.7 (5.2)	50.3 (6.8)	45.7 (10.0)	0.208
Resting metabolism[a]:				
Energy expenditure (MJ/d)	7.04 (0.76)	6.84 (0.87)	6.81 (0.92)	0.731
Fat oxidation (%)	68.9 (7.8)	65.6 (16.1)	65.3 (14.6)	0.717
Carbohydrate oxidation (%)	31.1 (7.8)	34.4 (16.0)	34.7 (14.6)	0.714

Fat oxidation (g/h)	5.22 (0.90)	4.98 (1.74)	4.80 (1.14)	0.705
Carbohydrate oxidation (g/h)	6.00 (1.20)	6.00 (2.40)	6.60 (3.00)	0.863
Maximal fat oxidation during exercise[b]:				
Fat oxidation (g/min)	0.40 (0.36-0.45)[c,d]	0.29 (0.25-0.34)	0.24 (0.20-0.29)	<0.001
Fat oxidation (mg/kg/min)	5.26 (4.69-5.84)[c,d]	3.83 (3.27-4.40)	3.24 (2.68-3.80)	<0.001
Fat oxidation (mg/kgFFM/min)	6.93 (6.08-7.78)[d]	5.42 (4.58-6.26)	4.59 (3.76-5.42)	0.001
Fatmax (% $\dot{V}O_2max$)	38.3 (32.8-43.8)[d]	34.2 (28.7-39.6)	27.6 (22.2-33.0)	0.028

[a]Mean (standard deviation).

[b]Estimated marginal means (95% confidence interval) adjusted for BMI and percentage body fat.

[c]Chinese vs. Indian (*P* < 0.05)

[d]Chinese vs Malay (*P* < 0.05).

LT-MVPA, leisure-time moderate-to-vigorous physical activity; $\dot{V}O_2max$, maximal oxygen uptake; FFM, fat free mass; Fatmax, percentage of maximum oxygen uptake at which maximum fat oxidation occurred.