

Segmental Body Composition, Perceived Exertion, and Central Adiposity as Independent Determinants of Cardiorespiratory Fitness in Young Asian Adults

Yee-How Say

yeehows@sunway.edu.my

Sunway University

Audrey Siew Foong Kow

UCSI University

Kristin-Ann Zhe Mun Leong

Sunway University

Hui Wen Ng

Sunway University

Kai Jiat Lee

Sunway University

Trischen Arujunan

Sunway University

Geetha Letchumanan

Sunway University

Jack Bee Chook

Sunway University

Research Article

Keywords: Cardiorespiratory fitness, VO2max, Segmental body composition, Central adiposity, Waist circumference, Rating of Perceived Exertion, Young adults

Posted Date: July 23rd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10443262/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

**Segmental Body Composition, Perceived Exertion, and Central Adiposity as
Independent Determinants of Cardiorespiratory Fitness in Young Asian Adults**

Yee-How Say¹, Audrey Siew Foong Kow², Kristin-Ann Zhe Mun Leong¹, Hui Wen Ng¹,
Kai Jiat Lee¹, Trischen Arujunan¹, Geetha Letchumanan¹, Jack Bee Chook¹

¹Department of Biomedical Sciences, Jeffrey Cheah Sunway Medical School, Faculty of
Medical and Life Sciences, Sunway University, 5, Jalan Universiti, Bandar Sunway, 47500
Subang Jaya, Selangor, Malaysia.

²Faculty of Pharmaceutical Sciences, UCSI University, 1, Jalan UCSI, UCSI Heights, Taman
Connaught, Cheras, 56000 Kuala Lumpur, Malaysia.

*Corresponding author: yeehows@sunway.edu.my

Abstract

Background Cardiorespiratory fitness ($\text{VO}_{2\text{max}}$) is a key indicator of cardiovascular and metabolic health in young adults. While overall body mass and total body fat percentage (TBF) influence aerobic capacity, the independent predictive value of localized regional subcutaneous fat (SF) and regional skeletal muscle mass (SM) compartments remains unclear. This study evaluated the independent anthropometric, segmental body composition, clinical, and exertional correlates of $\text{VO}_{2\text{max}}$ in young adults.

Methods A cross-sectional study was conducted among 726 young Asian adults (57.7% females; median age 21 ± 2 years) in Malaysia. Physical health metrics, central adiposity (waist circumference [WC]), and bioelectrical impedance measures of TBF and segmental tissue percentages—including whole-body, trunk, arm, and leg subcutaneous fat (SF) and skeletal muscle (SM)—were assessed. $\text{VO}_{2\text{max}}$ was evaluated via the three-minute step test, and submaximal Rating of Perceived Exertion (RPE) was recorded. A multivariable Generalized Linear Model identified independent predictors of $\text{VO}_{2\text{max}}$.

Results Male sex emerged as the strongest positive predictor of $\text{VO}_{2\text{max}}$ ($B = 17.769, p < 0.001$). Overall TBF ($B = -0.295, p = 0.013$) and WC ($B = -0.237, p = 0.027$) maintained significant negative independent associations with $\text{VO}_{2\text{max}}$. Controlling for TBF and WC eliminated the statistical significance of all individual segmental SF ($p > 0.05$). In adjusted models, upper-body muscle parameters exhibited mathematical suppression effects (Trunk SM: $B = -0.013, p = 0.009$; Arms SM: $B = -0.285, p = 0.022$), while submaximal RPE acted as a strong, inverse independent predictor of aerobic capacity ($B = -0.486, p < 0.001$).

Conclusion Male sex, lower TBF, lower central adiposity (WC), and lower submaximal perceived exertion (RPE) are the primary independent predictors of superior $\text{VO}_{2\text{max}}$ in young Asian adults. Systemic total fat burden and central abdominal adiposity exert a more pronounced negative impact on aerobic capacity than regional subcutaneous fat distribution.

Keywords Cardiorespiratory fitness; $\text{VO}_{2\text{max}}$; Segmental body composition; Central adiposity; Waist circumference; Rating of Perceived Exertion; Young adults.

Background

Cardiorespiratory fitness ($\text{VO}_{2\text{max}}$) is widely recognized as a critical clinical vital sign and a primary determinant of long-term cardiovascular and metabolic health [1]. Superior levels of cardiorespiratory fitness in young adults are strongly protective against the development of early subclinical atherosclerosis, insulin resistance, type 2 diabetes mellitus, and premature all-cause mortality [1,2]. Despite these well-established physiological benefits, global physical activity levels among young adults have steadily declined [3], giving rise to an increasing prevalence of early-onset obesity and suboptimal aerobic capacity [4]. Understanding the individual determinants of $\text{VO}_{2\text{max}}$ during early adulthood is therefore essential for designing targeted preventive lifestyle interventions before cardiometabolic disease risk consolidates in later life [5].

Body composition is a key physical factor influencing cardiorespiratory performance [6,7]. Relative oxygen uptake (ml/kg/min) inherently reflects the ratio of metabolically active motor units to non-contractile tissue mass [8]. Traditional anthropometric indicators, such as Body Mass Index (BMI), are frequently utilized in epidemiological surveys to approximate the association between adiposity and cardiorespiratory or musculoskeletal fitness [7,9–11]. However, BMI fails to distinguish between fat-free mass and adipose tissue and cannot capture regional tissue distribution [12]. Excess total body fat (TBF) acts as a non-metabolic inertial load during exercise, placing an oxidative burden on oxygen transport systems [13,14]. Conversely, central fat accumulation, indexed by waist circumference (WC) and Visceral Fat Level (VFL), triggers low-grade vascular inflammation, reduced arterial compliance, altered vascular tone, and metabolic inflexibility during dynamic exercise [15,16].

While the general negative relationship between overall adiposity and relative aerobic capacity is well-documented [7,8,13], the independent contributions of segmental tissue compartments remain less clear. In particular, it remains uncertain whether regional subcutaneous fat (SF) depots (whole, trunk, arms, and legs) exert direct, localized physiological constraints on $\text{VO}_{2\text{max}}$, or if their apparent effects are secondary to total systemic body fat (TBF) and central abdominal adiposity (WC). Furthermore, although lower-limb skeletal muscle (SM) mass (Legs SM) provides the principal metabolic and mechanical work during treadmill locomotion [17], the relative impact of upper-body regional muscle compartments (trunk SM, arms SM) within fully adjusted multivariable body composition models requires detailed clarification.

Beyond structural morphology, perceptual responses during exercise provide functional insight into cardiorespiratory strain [18]. Submaximal rating of perceived exertion (RPE) integrates central cardiorespiratory drive, peripheral muscular fatigue, and metabolic acidosis [18]. Evaluating RPE alongside segmental body composition parameters can help determine whether subjective perceptual exertion serves as a robust surrogate metric for $\text{VO}_{2\text{max}}$ in young adults [19].

Therefore, this study aimed to investigate the demographic, clinical, anthropometric, and segmental body composition correlates of $\text{VO}_{2\text{max}}$ in a sample of young Asian adults using a multivariable Generalized Linear Model framework. We specifically evaluated whether regional SF compartments maintain independent predictive value for aerobic capacity when accounting for systemic adiposity (TBF), central fat accumulation (WC), regional muscle mass (SM), and submaximal exertional perception (RPE).

Methods

Study design and participants

A cross-sectional study design was employed to evaluate the relationship between segmental body composition, perceived exertion, socio-demographic parameters, and cardiorespiratory fitness (VO_{2max}) in young adults. A total of 726 male ($n = 307$) and female ($n = 419$) participants aged 18 to 40 years were recruited via a convenience sampling method from three private higher education institutions in Malaysia, namely Sunway University, Sunway College (both comprising 58.1%), and UCSI University (comprising 41.9%), from May to July 2023, November to April, 2024 and May to July, 2026. This was done through the distribution of flyers around Sunway University, Sunway College, and UCSI University campuses and through social media platforms. The inclusion criteria were: (1) aged between 18 – 25 years, (2) a student from Sunway College, Sunway University, or UCSI University, (3) understands English, (4) able to walk without an assistive device, and (5) have no heart, lung, blood, muscle, or bone problems that prevent them from walking, standing from a chair, or climbing steps. Using the Raosoft sample size online calculator (<http://www.raosoft.com/samplesize.html>), a minimum sample size of 381 is needed to achieve a 5% margin of error, 90% confidence level, combined Sunway University, Sunway College, and UCSI University population size of 40,000, and a 50% response distribution. The study was conducted in accordance with the Declaration of Helsinki, and ethical approval was obtained from the Sunway University Research Ethics Committee (SUREC 2023/012) and UCSI University Institutional Research Ethics Committee (IEC-2024-FPS-0003). All participants provided written informed consent prior to data collection.

Measures

Data acquisition was executed over a scheduled timeframe and comprised two primary evaluation phases: self-administered survey instruments and objective physiological appraisals. Participants initially completed a battery of self-report questionnaires designed to

collect socio-demographic characteristics. Subsequently, trained investigative personnel administered a standardized battery of physical, anthropometric, and body composition assessments. This sequential approach maintained protocol uniformity and reduced inter-examiner measurement variance across the study population.

Socio-demographic and Lifestyle Factors

Recorded socio-demographic variables encompassed participant age, sex, ethnic background, highest educational qualification, and monthly household income. Household financial tier was classified according to official Malaysian economic benchmarks into three distinct brackets: B40 (bottom 40%, representing lower income; < MYR 4,850 or ~USD 1,152), M40 (middle 40%, representing middle income; MYR 4,851–10,970 or ~USD 1,153–2,605), and T20 (top 20%, representing higher income; > MYR 10,971 or ~USD 2,606). Self-report items were also utilized to ascertain health-related lifestyle behaviours, specifically current tobacco use and alcohol consumption habits.

Clinical, anthropometric, and body composition measurements

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were taken using an automated blood pressure monitor (HEM-7121, Omron, Japan) after the subjects had rested for 5 min. Blood pressure status was categorized according to standard clinical criteria into normal, Stage 1 hypertension, and Stage 2 hypertension [20]. Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Waist and hip circumferences were measured using a stretch-resistant tape that provided a constant 100 g tension, at the midpoint between the lower margin of the least palpable rib and the top of the iliac crest and around the widest portion of the buttocks, respectively [21]. The waist-hip ratio (WHR) and waist-to-height ratio (WHtR) were calculated by dividing waist circumference by hip circumference and height, respectively.

A bioimpedance body composition scale (Omron HBF-375) was used to determine weight, body mass index (BMI; kg/m²), total body fat (TBF; %), visceral fat level (VFL; %), subcutaneous fat (SF; %), skeletal muscle percentage (SM; %) and resting metabolism rate (RM; kcal). The cut-off points for overweight, obesity, high TBF, high VFL, high SM, high WC, high WHR and high WHtR are ≥ 23 kg/m² [22]; ≥ 27.5 kg/m² [22]; 20% (men) or 30% (women) [23]; 10% [23]; 35.8% (men) or 28% (women) [23]; 90 cm (men) or 80 cm (women) [22]; 0.90 (men) or 0.85 (women) [21]; and 0.50 [24], respectively.

Assessment of Cardiorespiratory Fitness (VO_{2max}) and Perceived Exertion

Cardiorespiratory fitness (VO_{2max}) was determined through the three-minute step test (TMST) [25–27]. Participants were asked to step on and off a 30 cm step, 24 times per minute for 3 minutes. They were aided in this endeavour by a metronome set at 96 beats per minute (bpm), which they were to match with 96 steps (24 ascent-descent cycles) per minute. Immediately after completion of the test, the participants' pulse rate was measured for 1 min using the SB200 Fingertip Pulse Oximeter (Rossmax International Ltd., Taiwan). VO_{2max} (ml/kg/min) was calculated using the formula: $111.33 - (0.42 \times \text{heart rate in bpm})$ for males and $65.81 - (0.1847 \times \text{heart rate in bpm})$ for females [28]. The VO_{2max} values were further categorized into age- and sex-normative classifications: Superior, Excellent, Above Average, Average, and Below Average [29]. For categorical risk analysis, participants were further dichotomized into an Optimal fitness group (comprising Superior, Excellent, and Above Average classifications) and a Suboptimal fitness group (comprising Average and Below Average classifications). Subjective exercise intensity was assessed during submaximal stages using Borg's 6-20 Rating of Perceived Exertion (RPE) scale, where participants rated their overall exertional distress ranging from 6 ("no exertion at all") to 20 ("maximal exertion") [18].

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows version 26.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Kolmogorov–Smirnov test, with $p < 0.05$ indicating deviation from normal distribution. Continuous non-parametric variables were presented as median $\pm$ interquartile range (IQR), while categorical variables were expressed as frequencies and percentages (n , %). Differences in baseline characteristics and body composition parameters between male and female participants, as well as between Optimal and Suboptimal fitness groups, were evaluated using Pearson's Chi-square (χ^2) test for categorical variables and Mann-Whitney U test for continuous non-parametric variables. To determine the independent predictors of $\text{VO}_{2\text{max}}$, a Generalized Linear Model with a normal distribution and identity link function was constructed, and correction for non-normality was made using the robust estimator (often called the Huber-White sandwich estimator). The model simultaneously entered socio-demographic variables (sex, ethnicity, education, income), lifestyle factors (smoking, alcohol), age, blood pressure metrics (SBP, DBP), central anthropometrics (WC, WHR, WHtR, BMI), systemic adiposity and metabolism (TBF, VFL, RM, Body Age), regional subcutaneous fat metrics (Whole SF, Trunk SF, Arms SF, Legs SF), regional skeletal muscle metrics (Whole SM, Trunk SM, Arms SM, Legs SM), and submaximal exertional perception (RPE). Parameter estimates (B), standard errors (SE), 95% Wald confidence intervals (95% CI), and Wald Chi-Square statistics were derived. A significance level of $p < 0.05$ was set for all statistical tests.

Results

Baseline Characteristics of Participants

A total of 726 young Asian adults participated in the study, comprising 307 males and 419 females (Table 1). The median age of the overall cohort was 21 ± 2 years, with no

statistically significant difference observed between male and female participants ($p = 0.637$). The vast majority of the study population (97.8 %) fell within the young adult age range of 18-25 yr, was ethnically Chinese (80.0%), had attained tertiary education (91.2%), and were single (98.8%). Male participants reported significantly higher rates of current smoking compared to female participants (9.4% vs. 3.6%, $p = 0.001$). The overall median VO_{2max} across all participants was 44.02 ± 16.60 mL/kg/min; male participants demonstrated significantly higher cardiorespiratory fitness levels compared to female participants (59.25 ± 10.90 vs. 41.06 ± 4.20 mL/kg/min, $p < 0.001$). Consequently, the distribution of VO_{2max} classifications differed markedly between sexes ($p < 0.001$), with 82.5% of male participants classified into the "Superior" or "Excellent" categories compared to only 4.7% of female participants. In terms of clinical, body composition, and anthropometric metrics, male participants exhibited significantly higher prevalence rates of Stage 1 or Stage 2 hypertension (4.5 vs. 0%, $p < 0.001$), high VFL (13.2 vs. 2.0%, $p < 0.001$), overweight or obesity (39.4 vs. 19.9%, $p < 0.001$), and high SM (44.3 vs. 29.4%, $p < 0.001$). Conversely, no statistically significant differences between sexes were observed regarding the prevalence of high WC or high TBF.

Associations with Cardiorespiratory Fitness Classification

Participants were recategorized into an Optimal group ($n = 425$, encompassing Superior, Excellent, and Above Average classifications) and a Suboptimal group ($n = 264$, encompassing Average, Below Average, and Poor classifications) based on their VO_{2max} performance (Table 2). Chi-square analyses demonstrated significant associations between cardiorespiratory fitness classification and several anthropometric and body composition parameters. A significantly higher proportion of participants in the Suboptimal fitness group presented with elevated WC compared to those in the Optimal group (15.9 vs. 10.6%, $p = 0.041$). Similarly, high TBF was significantly more prevalent among individuals in the

Suboptimal fitness category (37.9 vs. 30.1%, $p = 0.035$). BMI categories also differed significantly according to fitness level ($p = 0.041$), which was largely driven by a higher proportion of elevated muscle mass among fit male participants. Furthermore, a high SM was significantly associated with placement in the Optimal fitness group (40.5 vs. 27.7%, $p = 0.001$). In contrast, ethnicity, hypertension status, WHR, WHtR, and VFL showed no statistically significant associations with cardiorespiratory fitness classification.

Generalized Linear Model Predictors of VO_{2max}

To establish the independent determinants of continuous VO_{2max} , a Generalized Linear Model was executed while simultaneously adjusting for demographic, socioeconomic, lifestyle, anthropometric, body composition, and exertion factors (Table 3). Male sex emerged as the strongest positive independent predictor of continuous VO_{2max} ($B = 17.769$; 95% CI: 15.043, 20.494; $p < 0.001$). Other demographic, socioeconomic, and lifestyle factors—including ethnicity, educational attainment, household income category, smoking status, alcohol consumption, age, blood pressure, and body age—exhibited no statistically significant independent associations with VO_{2max} ($p > 0.05$ for all). With respect to adiposity measures, TBF was identified as a statistically significant negative independent predictor of VO_{2max} ($B = -0.295$; 95% CI: -0.528, -0.063; $p = 0.013$). Central adiposity assessed via WC also significantly predicted lower cardiorespiratory fitness ($B = -0.237$; 95% CI: -0.448, -0.027; $p = 0.027$). Crucially, once overall TBF and WC were controlled for, none of the specific sectional or whole-body SF compartments (whole body, trunk, arms, legs) maintained statistical significance ($p > 0.05$ for all). Similarly, BMI, WHR, WHtR, and VFL showed no significant independent predictive capacity in the adjusted model. When examining muscle compartments and subjective exercise intensity, specific regional muscle percentages demonstrated significant inverse parameters in the fully adjusted model, including trunk SM

($B = -0.013$; 95% CI: $-0.023, -0.003$; $p = 0.009$) and arms SM ($B = -0.285$; 95% CI: $-0.529, -0.042$; $p = 0.022$). Whole-body SM and leg SM were not statistically significant. Finally, RPE during submaximal exercise functioned as a robust, inverse independent predictor of aerobic capacity ($B = -0.486$; 95% CI: $-0.665, -0.308$; $p < 0.001$), demonstrating that higher perceived exertion during the TMST directly predicted lower VO_{2max} .

Discussion

The present study investigated the demographic, clinical, anthropometric, and segmental body composition correlates of VO_{2max} in a sample of young Asian adults. The primary findings demonstrate that male sex, TBF, WC, specific regional SM parameters, and submaximal RPE serve as key independent predictors of VO_{2max} . Significantly, when controlling for overall adiposity and central fat deposition, regional SF compartments lost predictive significance, underlining the predominant influence of systemic and visceral adiposity over localized subcutaneous depots on aerobic capacity.

Sex Differences in Cardiorespiratory Fitness and Health Profile

In agreement with established physiological literature, sex was the single strongest positive predictor of VO_{2max} . Male participants demonstrated markedly higher absolute and relative cardiorespiratory fitness compared to females (59.25 vs. 41.06 mL/kg/min). These sexual dimorphisms in exercise capacity stem from biological differences in maximal oxygen transport and utilization, including larger cardiac chamber sizes, higher haemoglobin concentrations, greater stroke volume, and higher average SM percentages in males [30–32]. However, despite achieving superior fitness categories, young adult males exhibited elevated cardiometabolic risk profiles compared to females, characterized by higher rates of Stage 1/2 hypertension (4.5 vs. 0%), elevated VFL (13.2 vs. 2.0%), and current tobacco use (9.4 vs.

3.6%). This paradoxical divergence highlights that high cardiorespiratory fitness does not entirely shield young men from early metabolic or cardiovascular risk factors, emphasizing the need for targeted health screening in young adult populations.

Impact of Adiposity and Fat Distribution on Aerobic Capacity

Both univariate cross-tabulations and adjusted parameter estimates confirmed that excess body fat acts as an independent physiological constraint on VO_{2max} . Because relative VO_{2max} is mathematically scaled per unit of total body mass (kg/ml/min), non-metabolically active adipose tissue increases inert heavy mass without contributing directly to oxidative phosphorylation, thereby imposing an immediate scaling penalty on relative oxygen consumption [33,34]. In the fully adjusted multivariable model, overall TBF and central adiposity via WC maintained negative independent associations with VO_{2max} . Interestingly, while initial univariate analyses showed associations between submaximal fitness groups and TBF (Table 2), non-central segmental SF compartments (whole body, trunk, arms, and legs) did not retain independent statistical significance in the multivariable model once overall TBF and WC were included. This indicates that central adiposity and total body fat mass exert a far greater influence on systemic cardiorespiratory kinetics than localized subcutaneous fat distribution. Central adiposity, represented by higher WC, is associated with systemic subclinical inflammation, altered vascular tone, and impaired metabolic flexibility during exercise [1,15]. These findings also align with prior physiological investigations demonstrating that total and central fat accumulations impair systemic oxygen transport kinetics and decrease running efficiency during incremental treadmill exertion [35,36].

Skeletal Muscle Compartments and Perceived Exertion

While total SM percentage was higher among the optimal fitness cohort in univariate testing, regional muscle parameters (trunk and arms) exhibited subtle negative parameter estimates in the fully adjusted multivariable model. This inverse relationship in multivariable regression reflects a classic mathematical suppression effect common in body composition modelling. Once sex, TBF, and overall body weight are simultaneously held constant, upper-body muscle mass acts as non-locomotor mass during upright treadmill walking/running. Because lower-limb musculature (legs SM) serves as the primary motor driver for treadmill locomotion, trunk and upper-limb SM add overall structural weight without directly contributing to the primary metabolic or propulsive work required to drive treadmill oxygen uptake [17]. Consequently, when total mass and adiposity are controlled, non-locomotor muscle mass effectively acts as additional dead weight during lower-body exertion.

Submaximal RPE emerged as a highly robust, independent predictor of $\text{VO}_{2\text{max}}$. Participants reporting higher perceived exertion at standard submaximal workloads exhibited lower aerobic capacity. Perceptual ratings during submaximal work act as a psychophysiological integration of central cardiovascular strain, respiratory drive, motor unit recruitment rates, peripheral metabolic acidosis, and sensory feedback via group III and IV muscle afferents [37,38]. Individuals with lower intrinsic $\text{VO}_{2\text{max}}$ operate at a higher relative percentage of their maximal aerobic capacity at any absolute submaximal treadmill stage, resulting in accelerated glycogen depletion, earlier anaerobic threshold accumulation, and heightened exertional distress [39]. Our findings validate submaximal RPE as a reliable, non-invasive surrogate metric for cardiorespiratory fitness [19,40,41], offering practical utility in clinical or community settings where maximal treadmill protocols are unsafe or infeasible.

Strengths and Limitations

A primary strength of this study lies in its robust sample size ($N = 726$) composed entirely of Asian young adults, a critical demographic window where metabolic risk factors and cardiorespiratory habits consolidate prior to midlife cardiometabolic disease onset. Furthermore, unlike conventional studies that rely solely on crude anthropometric indices such as BMI, this investigation utilized advanced bioelectrical impedance and segmental partitioning to evaluate both whole-body and localized regional body composition metrics (whole body, trunk, arms, and legs SF and SM). The application of a multivariable Generalized Linear Model permitted the simultaneous control of potential socio-demographic, lifestyle, clinical, and physiological confounders—including income, education, smoking, drinking, blood pressure, and submaximal exercise exertion (RPE)—thereby isolating the true independent parameter estimates of segmental tissue compartments on $\text{VO}_{2\text{max}}$.

Nevertheless, several methodological and design limitations warrant consideration. First, the cross-sectional nature of the study design inherently precludes inferences regarding direct causality between shifts in body composition or submaximal exertion and longitudinal changes in cardiorespiratory capacity. Second, the study population was predominantly comprised of tertiary-educated single individuals of Chinese ethnicity (80.0%), which may limit the direct generalizability of these specific parameter estimates to broader multi-ethnic cohorts, older age brackets, or populations with differing socio-demographic profiles. Third, while RPE during submaximal treadmill exercise proved to be a highly significant predictor, perceptual responses can be influenced by unmeasured psychological factors such as acute motivation, somatic anxiety, or unfamiliarity with standardized exercise testing equipment [42]. Finally, although segmental SF and SM percentages were comprehensively assessed, future studies employing advanced imaging modalities—such as Dual-Energy X-ray Absorptiometry or Magnetic Resonance Imaging—could provide enhanced resolution between deep visceral, intramuscular, and superficial subcutaneous tissue layers.

349

350 **Conclusions**

351 In conclusion, this study demonstrates that male sex, overall TBF percentage, central adiposity
352 via WC, and submaximal RPE serve as the primary independent determinants of
353 cardiorespiratory fitness (VO_{2max}) in young Asian adults. Significantly, when controlling for
354 global fat mass and WC, localized regional SF compartments offer no incremental predictive
355 value for aerobic capacity. From a practical and clinical perspective, these findings suggest that
356 obesity education and exercise intervention frameworks targeting young adults should
357 prioritize global fat mass reduction and the improvement of subjective workload tolerance
358 (RPE) over localized regional body composition modification. Monitoring submaximal
359 perceived exertion provides a simple, non-invasive, and robust surrogate indicator of
360 cardiorespiratory fitness in community and clinical settings.

361

362 **List of Abbreviations**

363 BIA: Bioelectrical Impedance Analysis

364 BMI: Body Mass Index

365 DBP: Diastolic Blood Pressure

366 IQR: Interquartile Range

367 RM: Resting Metabolism

368 RPE: Rating of Perceived Exertion

369 SBP: Systolic Blood Pressure

370 SF: Subcutaneous Fat

371 SM: Skeletal Muscle

372 TBF: Total Body Fat

373 TMST: Three-Minute Step Test

374 VFL: Visceral Fat Level
375 VO_{2max}: Maximal Oxygen Consumption
376 WC: Waist Circumference
377 WHR: Waist-to-Hip Ratio
378 WHtR: Waist-to-Height Ratio

379

380 **Acknowledgements**

381 The authors would like to thank all participants for participating in this study. We would also
382 like to thank Alex Ern Che Lee, Roxanne Shin Hee Lim, and the Year 1 2024 cohort of
383 Bachelor of Pharmacy (Honours), UCSI University, for their assistance in performing the
384 measurements and fitness test.

385

386 **Authors' contributions**

387 Y-H S & ASFK: Conceptualization, Formal analysis, Methodology, Supervision, Validation,
388 Visualisation, Writing – original draft, Writing – review & editing.

389 K-A ZML, HWN, KJL, TA: Data curation, Formal analysis, Investigation, Validation,
390 Visualization, Writing – original draft.

391 GL: Supervision, Validation, Visualisation, Writing – review & editing.

392 JBC: Methodology, Supervision, Validation, Visualisation, Writing – review & editing.

393

394 **Funding**

395 This research is supported by the Malaysian Ministry of Higher Education Fundamental Grant
396 Research Scheme FRGS/1/2022/STG01/SYUC/02/1 and UCSI University Research
397 Excellence and Innovation Grant REIG-FPS-2025/030. The funders had no role in the design

of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Data availability

The datasets used and analysed during the current study are available from the corresponding author on reasonable requests.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki, and ethical approval was obtained from the Sunway University Research Ethics Committee (SUREC 2023/012) and UCSI University Institutional Research Ethics Committee (IEC-2024-FPS-0003. All participants provided written informed consent prior to data collection.

Consent for publication

Not applicable

Competing interests

All authors declare that they have no competing interests.

References

1. Ross R, Blair SN, Arena R, Church TS, Després J-P, Franklin BA, et al. Importance of Assessing Cardiorespiratory Fitness in Clinical Practice: A Case for Fitness as a Clinical Vital Sign: A Scientific Statement From the American Heart Association. *Circulation* [Internet]. 2016 [cited 2026 Apr 20];134. <https://doi.org/10.1161/CIR.0000000000000461>

2. Chu DJ, Al Rifai M, Virani SS, Bawner CA, Nasir K, Al-Mallah MH. The relationship between cardiorespiratory fitness, cardiovascular risk factors and atherosclerosis. *Atherosclerosis*. 2020;304:44–52. <https://doi.org/10.1016/j.atherosclerosis.2020.04.019>
3. World Health Organisation (WHO). Global levels of physical inactivity in adults: off track for 2030 [Internet]. World Health Organisation (WHO); 2024 [cited 2026 Jul 22]. <https://iris.who.int/handle/10665/378026>. Accessed 22 Jul 2026
4. Ng M, Gakidou E, Lo J, Abate YH, Abbafati C, Abbas N, et al. Global, regional, and national prevalence of adult overweight and obesity, 1990–2021, with forecasts to 2050: a forecasting study for the Global Burden of Disease Study 2021. *The Lancet*. 2025;405:813–38. [https://doi.org/10.1016/S0140-6736\(25\)00355-1](https://doi.org/10.1016/S0140-6736(25)00355-1)
5. Scott J, Agarwala A, Baker-Smith CM, Feinstein MJ, Jakubowski K, Kaar J, et al. Cardiovascular Health in the Transition From Adolescence to Emerging Adulthood: A Scientific Statement From the American Heart Association. *JAHA*. 2025;14:e039239. <https://doi.org/10.1161/JAHA.124.039239>
6. Ho C-A, Yeh H-C, Lau H-T, Chang E-Y, Hsu C-W, Chang C-H, et al. Establish VO₂max prediction models based on exercise and body parameters from the step test. *Int J Med Sci*. 2025;22:2676–85. <https://doi.org/10.7150/ijms.109977>
7. Mondal H, Mishra SP. Effect of BMI, Body Fat Percentage and Fat Free Mass on Maximal Oxygen Consumption in Healthy Young Adults. *J Clin Diagn Res*. 2017;11:CC17–20. <https://doi.org/10.7860/JCDR/2017/25465.10039>
8. Zhou N. Assessment of aerobic exercise capacity in obesity, which expression of oxygen uptake is the best? *Sports Med Health Sci*. 2021;3:138–47. <https://doi.org/10.1016/j.smhs.2021.01.001>
9. Ajdinović A, Mahmutović E, Biševac E, Salihagić Z, Safiye T, Radenković O, et al. Relationship Between Physical Fitness Index and Body Mass Index: A Cross-Sectional Study

448 in Serbian Students of Biomedical Sciences. JFMK. 2025;10:449.
 449 <https://doi.org/10.3390/jfmk10040449>

450 10. Bonney E, Ferguson G, Smits-Engelsman B. Relationship between Body Mass Index,
 451 Cardiorespiratory and Musculoskeletal Fitness among South African Adolescent Girls. Int J
 452 Environ Res Public Health. 2018;15:1087. <https://doi.org/10.3390/ijerph15061087>

453 11. Gong H, Zhao Y. The relationship between Body Mass Index and Physical Fitness Index
 454 among college students: a cross-sectional study in Yangzhou, China. Front Public Health.
 455 2026;14:1780690. <https://doi.org/10.3389/fpubh.2026.1780690>

456 12. Prillaman M. Why BMI is flawed — and how to redefine obesity. Nature. 2023;622:232–
 457 3. <https://doi.org/10.1038/d41586-023-03143-x>

458 13. Norman A-C, Drinkard B, McDuffie JR, Ghorbani S, Yanoff LB, Yanovski JA. Influence
 459 of excess adiposity on exercise fitness and performance in overweight children and adolescents.
 460 Pediatrics. 2005;115:e690-696. <https://doi.org/10.1542/peds.2004-1543>

461 14. Muscella A, Stefano E, Lunetti P, Capobianco L, Marsigliante S. The Regulation of Fat
 462 Metabolism During Aerobic Exercise. Biomolecules. 2020;10:1699.
 463 <https://doi.org/10.3390/biom10121699>

464 15. Turner L, Wanasinghe AI, Brunori P, Santosa S. Is Adipose Tissue Inflammation the
 465 Culprit of Obesity-Associated Comorbidities? Obes Rev. 2025;26:e13956.
 466 <https://doi.org/10.1111/obr.13956>

467 16. Lee M-J, Kim J. The pathophysiology of visceral adipose tissues in cardiometabolic
 468 diseases. Biochem Pharmacol. 2024;222:116116. <https://doi.org/10.1016/j.bcp.2024.116116>

469 17. Mazaheri R, Sanjari MA, Radmehr G, Halabchi F, Angoorani H. The Activation Pattern of
 470 Trunk and Lower Limb Muscles in an Electromyographic Assessment; Comparison Between
 471 Ground and Treadmill Walking. Asian J Sports Med. 2016;7:e35308.
 472 <https://doi.org/10.5812/asjasm.35308>

- 473 18. Borg GAV. Borg's Perceived exertion and pain scales. Champaign, Ill.: Human Kinetics;
474 1998.
- 475 19. Coquart JB, Garcin M, Parfitt G, Tourny-Chollet C, Eston RG. Prediction of Maximal or
476 Peak Oxygen Uptake from Ratings of Perceived Exertion. *Sports Med.* 2014;44:563–78.
477 <https://doi.org/10.1007/s40279-013-0139-5>
- 478 20. Whelton PK, Carey RM, Aronow WS, Casey DE, Collins KJ, Dennison Himmelfarb C, et
479 al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for
480 the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: A
481 Report of the American College of Cardiology/American Heart Association Task Force on
482 Clinical Practice Guidelines. *Hypertension* [Internet]. 2018 [cited 2026 Jul 22];71.
483 <https://doi.org/10.1161/HYP.0000000000000065>
- 484 21. WHO. Waist Circumference and Waist–Hip Ratio: Report of a WHO Expert Consultation
485 [Internet]. WHO Expert Consultation; 2011 [cited 2023 Jul 25].
486 https://apps.who.int/iris/bitstream/handle/10665/44583/9789241501491_eng.pdf. Accessed
487 25 Jul 2023
- 488 22. WHO/IOTF/IASO. The Asia-Pacific perspective: redefining obesity and its treatment.
489 World Health Organization, International Obesity Task Force, International Association for the
490 Study of Obesity; 2000.
- 491 23. Omron. Instruction Manual - Body Composition Monitor Model HBF-375 KaradaScan
492 (TM) [Internet]. [cited 2023 Jul 25]. [https://www.omronhealthcare-](https://www.omronhealthcare-ap.com/Content/uploads/products/789b8222779742fe808151a86d9851e4.pdf)
493 [ap.com/Content/uploads/products/789b8222779742fe808151a86d9851e4.pdf](https://www.omronhealthcare-ap.com/Content/uploads/products/789b8222779742fe808151a86d9851e4.pdf). Accessed 25
494 Jul 2023
- 495 24. Ashwell M, Hsieh SD. Six reasons why the waist-to-height ratio is a rapid and effective
496 global indicator for health risks of obesity and how its use could simplify the international

- public health message on obesity. *International Journal of Food Sciences and Nutrition*. 2005;56:303–7. <https://doi.org/10.1080/09637480500195066>
25. YMCA of the USA, editor. *YMCA fitness testing and assessment manual*. 4th ed. Champaign, Ill.: Published for the YMCA of the USA by Human Kinetics; 2000.
26. Chung J, Lee K. A Comparison of the Validity of Three Exercise Tests for Estimating Maximal Oxygen Uptake in Korean Adults Aged 19–64 Years. *Applied Sciences*. 2022;12:1371. <https://doi.org/10.3390/app12031371>
27. Kieu NTV, Jung S-J, Shin S-W, Jung H-W, Jung E-S, Won YH, et al. The Validity of the YMCA 3-Minute Step Test for Estimating Maximal Oxygen Uptake in Healthy Korean and Vietnamese Adults. *J Lifestyle Med*. 2020;10:21–9. <https://doi.org/10.15280/jlm.2020.10.1.21>
28. Mc Ardle WD, Katch FI, Katch VL. *Exercise physiology: nutrition, energy, and human performance*. 7th ed. Philadelphia: Wolters kluwer health - Lippincott Williams & Wilkins; 2010.
29. Golding LA, Meyers CR, Sinning WE. *Y’s Way to Physical Fitness: The Complete Guide to Fitness Testing and Instruction*. Human Kinetics; 1989.
30. Skattebo Ø, Martin-Rincon M, Rud B, Nielsen J, Hegg LHN, Kleive AV, et al. Determinants of maximal oxygen uptake in highly trained females and males: a mechanistic study of sex differences using advanced invasive methods. *The Journal of Physiology*. 2025;JP289218. <https://doi.org/10.1113/JP289218>
31. Holdsworth DA, O’Leary TJ, Doig CL, Taylor N, Dosanjh J, Woods DR, et al. Physiological Basis of Sex Differences in Human Performance and Exercise-Associated Pathology. *Clinical Endocrinology*. 2026;105:151–62. <https://doi.org/10.1111/cen.70150>
32. Santisteban KJ, Lovering AT, Halliwill JR, Minson CT. Sex Differences in VO₂max and the Impact on Endurance-Exercise Performance. *Int J Environ Res Public Health*. 2022;19:4946. <https://doi.org/10.3390/ijerph19094946>

- 522 33. Hadjicharalambous M, Apostolidis A, Zaras N, Chalari E, Tooba T, Faiz R, et al. The
523 Influence of Body Fat Percentage on Physiological Responses and Performance in Professional
524 Soccer Players During a Soccer Game Simulation Protocol on a Treadmill. *Sports (Basel)*.
525 Basel, Switzerland; 2026;14:156. <https://doi.org/10.3390/sports14040156>
- 526 34. Vasquez-bonilla AA, Rojas-Valverde D, Timon R, Olcina G. Influence of fat percentage
527 on muscle oxygen uptake and metabolic power during repeated-sprint ability of footballers.
528 *Apunts Sports Medicine*. 2022;57:100395. <https://doi.org/10.1016/j.apunsm.2022.100395>
- 529 35. Phoemsapthawee J, Phoemsapthawee S. Impaired oxygen consumption kinetics and
530 autonomic dysfunction contribute to increased fatigue in obese young males during sustained
531 exercise. *J Exerc Rehabil*. 2025;21:219–30. <https://doi.org/10.12965/jer.2550358.179>
- 532 36. Béres B, Györe I, Zsakai A, Dobronyi T, Bakonyi P, Szabó T. Submaximal Oxygen Deficit
533 During Incremental Treadmill Exercise in Elite Youth Female Handball Players. *Sports*
534 (Basel). Basel, Switzerland; 2025;13:252. <https://doi.org/10.3390/sports13080252>
- 535 37. Tornero-Aguilera JF, Jimenez-Morcillo J, Rubio-Zarapuz A, Clemente-Suárez VJ. Central
536 and Peripheral Fatigue in Physical Exercise Explained: A Narrative Review. *Int J Environ Res*
537 *Public Health*. 2022;19:3909. <https://doi.org/10.3390/ijerph19073909>
- 538 38. Zhao H, Kurokawa T, Tajima M, Liu Z, Okada J. Understanding perceived exertion in
539 power-aimed resistance training: the relationship between perceived exertion and muscle
540 fatigue. *PeerJ*. 2025;13:e20426. <https://doi.org/10.7717/peerj.20426>
- 541 39. Spagnolo A, Klug S, Schenkl C, Schwarzer M. Links between Exercise Capacity, Exercise
542 Training, and Metabolism. *Comprehensive Physiology*. 2023;13:5115–55.
543 <https://doi.org/10.1002/j.2040-4603.2023.tb00283.x>
- 544 40. Al-Rahamneh HQ, Faulkner JA, Byrne C, Eston RG. Prediction of peak oxygen uptake
545 from ratings of perceived exertion during arm exercise in able-bodied and persons with
546 poliomyelitis. *Spinal Cord*. 2011;49:131–5. <https://doi.org/10.1038/sc.2010.59>

41. Coquart JB, Eston RG, Lemaître F, Bart F, Tourny C, Grosbois J-M. Prediction of peak oxygen uptake from ratings of perceived exertion during a sub-maximal cardiopulmonary exercise test in patients with chronic obstructive pulmonary disease. *Eur J Appl Physiol.* 2015;115:365–72. <https://doi.org/10.1007/s00421-014-3023-6>
42. Hutchinson JC, Tenenbaum G. Perceived effort and exertion. In: Anshel MH, Petruzzello SJ, Labbé EE, editors. *APA handbook of sport and exercise psychology, volume 2: Exercise psychology (Vol 2)* [Internet]. Washington: American Psychological Association; 2019 [cited 2026 Jul 22]. p. 159–82. <https://doi.org/10.1037/0000124-009>

Table 1. Baseline demographic, lifestyle, anthropometric, body composition, and cardiorespiratory fitness characteristics of the participants

Variables	Male (<i>n</i> = 307; 42.3%)	Female (<i>n</i> = 419; 57.7%)	Total (<i>N</i> = 726)
Age (Median ± Interquartile Range); yr	21 ± 2	21 ± 2	21 ± 2
<i>p</i>	0.637		
VO _{2max} (Median ± Interquartile Range); ml/kg/min	59.25 ± 10.90	41.06 ± 4.20	44.02 ± 16.60
<i>p</i>	<0.001**		
Institution			
Sunway University	211 (68.7)	211 (50.4)	422 (58.1)
UCSI University	96 (31.3)	208 (49.6)	304 (41.9)
χ^2 ; <i>p</i>	24.570; <0.001**		
Age Group			
18-25	300 (97.7)	410 (97.9)	710 (97.8)
26-40	7 (2.3)	9 (2.1)	16 (2.2)
χ^2 ; <i>p</i>	0.014; 0.905		
Ethnicity			
Malay/Bumiputra	15 (4.9)	37 (8.8)	52 (7.2)
Chinese	243 (79.2)	338 (80.7)	581 (80.0)
Indian	38 (12.4)	38 (9.1)	76 (10.5)
Non-Malaysian Asian	11 (3.6)	6 (1.4)	17 (2.3)
χ^2 ; <i>p</i>	9.254; 0.026*		
Marital Status			

Single	301 (98.0)	416 (99.3)	717 (98.8)
Married	6 (2.0)	3 (0.7)	9 (1.2)
$\chi^2; p$	2.219; 0.136		
Highest Education Level			
Secondary	35 (11.4)	29 (6.9)	64 (8.8)
Tertiary	272 (88.6)	390 (93.1)	662 (91.2)
$\chi^2; p$	4.423; 0.035*		
Monthly Household Income			
B40 (< MYR 4,850 or USD 1,065)	106 (34.5)	110 (26.3)	216 (29.8)
M40 (MYR 4,851–10,970 or USD 1,066–2,406)	134 (43.6)	219 (52.3)	353 (48.6)
T20 (> MYR 10,971 or USD 2,407)	67 (21.8)	90 (21.5)	157 (21.6)
$\chi^2; p$	6.794; 0.033*		
Current Smoking Status			
Never/Quit	278 (90.6)	404 (96.4)	682 (93.9)
Current smoker	29 (9.4)	15 (3.6)	44 (6.1)
$\chi^2; p$	10.710; 0.001**		
Current Drinking Status			
Never/Monthly or less	204 (66.4)	306 (73.0)	510 (70.2)
Once a month or more	103 (33.6)	113 (27.0)	216 (29.8)
$\chi^2; p$	3.672; 0.055		
Hypertension Class			
Normal	274 (95.5)	402 (100)	676 (98.1)
Stage 1 hypertension	6 (2.1)	0	6 (0.9)
Stage 2 hypertension	7 (2.4)	0	7 (1.0)

$\chi^2; p$	18.559; <0.001**		
WC Class			
Normal	251 (87.5)	351 (87.3)	602 (87.4)
High	36 (12.5)	51 (12.7)	87 (12.6)
$\chi^2; p$	0.003; 0.956		
WHR Class			
Normal	251 (87.5)	363 (90.3)	614 (89.1)
High	36 (12.5)	39 (9.7)	75 (10.9)
$\chi^2; p$	1.394; 0.238		
WHtR Class			
Normal	235 (81.9)	352 (87.6)	587 (85.2)
High	52 (18.1)	50 (12.4)	102 (14.8)
$\chi^2; p$	4.284; 0.038*		
TBF Class			
Normal	181 (63.1)	280 (69.7)	461 (66.9)
High	106 (36.9)	122 (30.3)	228 (33.1)
$\chi^2; p$	3.280; 0.070		
VFL Class			
Normal	249 (86.8)	394 (98.0)	643 (93.3)
High	38 (13.2)	8 (2.0)	46 (6.7)
$\chi^2; p$	34.017; <0.001**		
BMI Class			
Normal	174 (60.6)	322 (80.1)	496 (72.0)
Overweight	84 (29.3)	59 (14.7)	143 (20.8)
Obese	29 (10.1)	21 (5.2)	50 (7.3)

$\chi^2; p$ 31.495; <0.001**

SM Class

Normal 160 (55.7) 284 (70.6) 444 (64.4)

High 127 (44.3) 118 (29.4) 245 (35.6)

$\chi^2; p$ 16.219; <0.001**

V_{O2Max} Class

Superior 131 (45.6) 0 131 (19.0)

Excellent 106 (36.9) 19 (4.7) 125 (18.1)

Above average 26 (9.1) 143 (35.6) 169 (24.5)

Average 16 (5.6) 178 (44.3) 194 (28.2)

Below average 8 (2.8) 62 (15.4) 70 (10.2)

$\chi^2; p$ 444.624; <0.001

574 WC: waist circumference, WHR: Waist-Hip Ratio, WHtR: Waist-Height Ratio, TBF: Total

575 Body Fat, VFL: Visceral Fat Level, BMI: Body Mass Index, SM: Skeletal Muscle Percentage

576 *p*-value significant at * < 0.05; **<0.01

577 Parentheses indicate percentage within same sex

578

579

580

581

582

583

584

585

586

587 **Table 2.** Association of VO2Max Class with ethnicity, anthropometric and body composition
588 classes

Variable	Optimal (Superior/Excellent/Above Average) (<i>n</i> = 425)		Suboptimal (Average/Below Average/Poor) (<i>n</i> = 264)	
Ethnicity				
Malay/Bumiputra		24 (5.6)		27 (10.2)
Chinese		353 (83.1)		206 (78.0)
Indian		37 (8.7)		28 (10.6)
Non-Malaysian				
Asian		11 (2.6)		3 (1.1)
$\chi^2; p$				7.435; 0.059
Hypertension				
Class				
Normal		413 (97.2)		263 (99.6)
Stage 1				
hypertension		6 (1.4)		0
Stage 2				
hypertension		6 (1.4)		1 (0.4)
$\chi^2; p$				5.537; 0.063
WC Class				
Normal		380 (89.4)		222 (84.1)
High		45 (10.6)		42 (15.9)
$\chi^2; p$				4.179; 0.041*

WHR Class

Normal	385 (90.6)	229 (86.7)
--------	------------	------------

High	40 (9.4)	35 (13.3)
------	----------	-----------

$\chi^2; p$	2.483; 0.115
-------------	--------------

WHtR Class

Normal	369 (86.8)	218 (82.6)
--------	------------	------------

High	56 (13.2)	46 (17.4)
------	-----------	-----------

$\chi^2; p$	2.330; 0.127
-------------	--------------

TBF Class

Normal	297 (69.9)	164 (62.1)
--------	------------	------------

High	128 (30.1)	100 (37.9)
------	------------	------------

$\chi^2; p$	4.430; 0.035*
-------------	---------------

VFL Class

Normal	394 (92.7)	249 (94.3)
--------	------------	------------

High	31 (7.3)	15 (5.7)
------	----------	----------

$\chi^2; p$	0.679; 0.410
-------------	--------------

BMI Class

Normal	296 (69.6)	200 (75.8)
--------	------------	------------

Overweight	101 (23.8)	42 (15.9)
------------	------------	-----------

Obese	28 (6.6)	22 (8.3)
-------	----------	----------

$\chi^2; p$	6.370; 0.041*
-------------	---------------

SM Class

Normal	253 (59.5)	191 (72.3)
--------	------------	------------

High	172 (40.5)	73 (27.7)
------	------------	-----------

$\chi^2; p$	11.678; 0.001**
-------------	-----------------

589 WC: waist circumference, WHR: Waist-Hip Ratio, WHtR: Waist-Height Ratio, TBF: Total
590 Body Fat, VFL: Visceral Fat Level, BMI: Body Mass Index, SM: Skeletal Muscle Percentage
591 *p*-value significant at * < 0.05; **<0.01

592 Parentheses indicate percentage within same VO2Max class

593

594

595

596

597

598

599

600

601

602

603

604

605

606

607

608

609

610

611

612

613

614 **Table 3.** Generalized Linear Model Parameter Estimates for Predictors of VO2Max Adjusted
615 for Demographic and Lifestyle Factors

Parameter	B	Std. Error	95% Wald CI Lower	95% Wald CI Upper	Wald Chi- Square	Sig.
Male sex	17.769	1.391	15.043	20.494	163.264	<0.001**
Malay/Bumiputra ethnicity	0.065	1.906	-3.672	3.801	0.001	0.973
Chinese ethnicity	-0.277	1.752	-3.710	3.156	0.025	0.874
Indian ethnicity	-0.182	1.943	-3.991	3.626	0.009	0.925
Secondary Education Level	0.132	0.730	-1.298	1.563	0.033	0.856
B40 Monthly Household Income	0.405	0.639	-0.848	1.657	0.401	0.527
M40 Monthly Household Income	0.977	0.581	-0.161	2.116	2.833	0.092
Not Current Smoker	1.820	1.197	-0.525	4.166	2.314	0.128
Never/Monthly or Less Current Alcohol Drinker	-0.148	0.509	-1.146	0.849	0.085	0.771
Age	0.169	0.105	-0.036	0.374	2.616	0.106
SBP	0.004	0.027	-0.049	0.056	0.019	0.891
DBP	-0.072	0.042	-0.155	0.011	2.860	0.091
WC	-0.237	0.107	-0.448	-0.027	4.880	0.027*
WHR	-1.475	2.620	-6.610	3.660	0.317	0.573

WHtR	20.616	16.945	-12.594	53.827	1.480	0.224
TBF	-0.295	0.119	-0.528	-0.063	6.212	0.013*
VFL	-0.069	0.069	-0.204	0.067	0.990	0.320
RM	0.002	0.002	-0.001	0.006	1.583	0.208
BMI	-0.061	0.203	-0.459	0.337	0.090	0.765
Body Age	0.015	0.084	-0.150	0.180	0.033	0.856
Whole SF	0.246	0.141	-0.031	0.522	3.039	0.081
Trunk SF	-0.017	0.015	-0.046	0.013	1.227	0.268
Arms SF	-0.173	0.095	-0.360	0.013	3.318	0.069
Legs SF	0.132	0.071	-0.008	0.271	3.431	0.064
Whole SM	0.019	0.228	-0.428	0.465	0.007	0.935
Trunk SM	-0.013	0.005	-0.023	-0.003	6.889	0.009**
Arms SM	-0.285	0.124	-0.529	-0.042	5.282	0.022*
Legs SM	0.173	0.100	-0.022	0.369	3.011	0.083
RPE	-0.486	0.091	-0.665	-0.308	28.414	<0.001**

SBP: systolic blood pressure, DBP: diastolic blood pressure, WC: waist circumference, WHR:
 Waist-Hip Ratio, WHtR: Waist-Height Ratio, TBF: Total Body Fat, VFL: Visceral Fat Level,
 BMI: Body Mass Index, SF: Subcutaneous Fat Level, SM: Skeletal Muscle Percentage, RPE:
 Borg's Rating of Perceived Exertion
p-value significant at * < 0.05; **<0.01