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Original Article

Correlation between physical activity, cardiorespiratory fitness and heart rate variability among young overweight adults

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الملخص

أهداف البحث: تقييم الوظيفة اللاإرادية للقلب من خلال تغير معدل ضربات القلب هو غير-تداخلي، كمي، ودلالة موثوقة للقياس. وظيفة القلب اللاإرادية المتغيرة بين الأفراد الذين يعانون من السمنة يعرضهم لخطر أكبر لحصول أمراض القلب والأوعية الدموية. تهدف هذه الدراسة لتحديد علاقة النشاط البدني واللياقة القلبية الرئوية مع تغير معدل ضربات القلب بين البالغين الذين يعانون من زيادة الوزن.

طرق البحث: ما مجموعه٤٥ مشاركا (٢٣= ذكور, ٢٢=إناث) التحقوا في هذه الدراسة- المقطعية في الأعمار بين ١٨-٣٠ عاما، مؤشر كتلة الجسم (كجم/ م٢) بين ٢٥-٢٩,٩ من غير أي حالة طبية معروفة او تم تشخيصها. تم قياس مستوى النشاط البدني بواسطة استبانة النشاط البدني العالمي واللياقة القلبية-الرئوية باستخدام اختبار جهاز بروس لبروتوكول المشي. تم قياس وظيفة القلب اللاإرادية باستخدام تسجيل تقلب معدل ضربات القلب على المدى القصير لمدة ٥ دقائق. تم استخدام مجال الوقت ومجال التردد لمتغيرات معدل ضربات القلب للتحليلات.

النتائج: كان متوسط عمر المشاركين في الدراسة ٢٢,٥٣±١,٥٨ عاما ومؤشر كتلة الجسم ٢٧,٣٨±١,٥١ كجم / م٢. تم تسجيل متغيرات التحول اللوغاريتمي الطبيعي لمعدل ضربات القلب لمجال الوقت ومجال التردد. بين البالغين الذين يعانون من زيادة الوزن، لا يوجد ترابط بين النشاط البدني واللياقة القلبية الرئوية مع الجذر التربيعي ما بين النبضات المتجاورة، النسبة التقريبية ما بين طول النبضة والنبضة الاخرى بحيث لا تزيد عن ٥٠ مل/ثانيه، و نسبة التردد المنخفض/التردد العالي.

الاستنتاجات: أظهرت هذه الدراسة انه لا توجد علاقة بين النشاط البدني واللياقة القلبية الرئوية مع تغير معدل ضربات القلب بين الأفراد الذين يعانون من زيادة الوزن.

الكلمات المفتاحية: السمنة؛ الجهاز العصبي اللاإرادي؛ قدرة استيعاب التمرين؛ اللياقة البدنية؛ ممارسة الرياضة

Abstract

Objective: Cardiac autonomic function assessed by heart rate variability (HRV) is a non-invasive, quantitative, and reliable marker of measurement. An altered cardiac autonomic function among overweight individuals predisposes them to a greater risk of developing cardiovascular diseases. The present study aims to determine the correlation between physical activity, cardiorespiratory fitness and heart rate variability among young overweight adults.

Methods: A total of 45 participants (23 men and 22 women) were enrolled in the cross-sectional study with inclusion criteria as follows: aged between 18—30 years, body mass index (kg/m²) between 25—29.9 kg/m², and without any known or diagnosed medical condition. Physical activity level and cardiorespiratory fitness were measured using the Global Physical Activity Questionnaire and Bruce treadmill protocol test, respectively. Cardiac autonomic function was measured using a 5-min short-term heart rate variability recording. The time and frequency domain measures of HRV were used for analysis.

Results: The mean age of study participants was 22.53 ± 1.58 years and mean body mass index was 27.38 ± 1.51 kg/m2. Among young overweight adults, cardiorespiratory fitness and physical activity were not

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correlated with Root mean square of successive RR interval differences, Percentage of successive RR intervals that differ by more than 50 ms, and Ratio of LF [ms2]/HF [ms2].

Conclusion: The study found no correlation between physical activity and cardiorespiratory fitness with heart rate variability among young overweight individuals.

Keywords: Adiposity; Autonomic nervous system; Exercise; Exercise capacity

Introduction

The public health concern of obesity has escalated from its previous global prevalence of 26.5% (1980) to 39% (2016), an alarming 50% increase over the last 35 years.[1] Obesity,[2] which is an endocrine disorder links multiple organ systems of the body. The physical and mental health of an individual is determined by the adequate release of hormones and balance of the autonomic nervous system. Any underlying cardiometabolic disturbance alters the normal trajectory of the cardiac autonomic functioning in the body, which has health implications.[3–5] Assessment of cardiac autonomic function (CAF) through heart rate variability (HRV) measurement is regarded as a simple, non-invasive, and reliable method.[6,7]

The risk of coronary heart disease, atrial fibrillation, sudden cardiac death, and overall mortality is increased in the event of low heart rate variability among the general population.[3] The regularisation of CAF through improved physical activity (PA) and cardiorespiratory fitness (CRF) has been observed and reported among physically active, normal-weight individuals.[8–11] Sedentary lifestyle predominates among overweight and obese individuals and contributes largely to cardiac autonomic dysfunction.[9] Interestingly, a 10% weight gain over initial body weight was reported to decrease parasympathetic tone and increase sympathetic tone among a group of non-obese individuals.[12,13] The evidence on how increasing adiposity may affect CAF among overweight and obese individuals is worth exploring. A plausible understanding of this relationship can help in the early identification of cardiac autonomic changes in clinical/healthcare settings by healthcare staff that is trained to interpret these findings. It may aid in optimal planning and devising of cost-effective strategies through lifestyle modification programs, behavioural change, and adoption of PA to improve CRF of individuals or groups at large.

A study by Tonello et al. reported a significant correlation between cardiorespiratory fitness and incidental or non-exercise-based PA with HRV among its study participants (overweight female workers).[14] Moreover, a study by Triggiani et al. observed a significant inverted U-shaped curve fitting the distribution of HRV parameters along with body fat percentage among its study participants (healthy women).[15] The evidence from such studies on overweight individuals shed light on how HRV transitions from individuals with a normal weight to those with high grades of obesity.

In this regard, there is a scarcity of evidence and literature focusing on the relationship between PA, CRF and HRV among young overweight individuals. For clarity, further research into the interactions between these variables is needed. Thus, the aim of the present study was to determine the correlation between PA, CRF and HRV among young overweight individuals.

Materials and Methods

Study design and setting

A cross-sectional study was conducted at the Cardiopulmonary Physiotherapy Laboratory of Kasturba Hospital, Manipal, Karnataka, India.

This study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines and the Declaration of Helsinki. The study was conducted from 11/07/2018 to 15/03/2019 (for approximately 8 months).

Participant recruitment and selection criteria

The research was verbally advertised to potential participants residing in the University campus of Manipal Academy of Higher Education, Karnataka, India. A total of 71 individuals consented to participate. A detailed screening process is shown in a flow diagram (Figure 1). Out of the 71 individuals, only 45 participants were found to be eligible and enrolled in the study. The participants belonged to either gender, had a body mass index (BMI) between 25–29.9 kg/m^2, were aged between 18 and 30 years, and had low risk on the AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire was included in the study.[17] The recruited participants were University students studying in the campus. The exclusion criteria were as follows: (i) any known diagnosis of (a) diabetes mellitus or hypertension, (b) cardiovascular and respiratory disorders, (c) neurological disorders, (d) metabolic diseases, (ii) use of alcohol or any type of prescribed medication, or a smoking history; and (iii) consumption of caffeine beverages 12 h before the HRV recording.

Data collection

Demographic data such as age, sex and medical history were collected. Anthropometric measurements were calculated using a fixed stadiometer (height) and the Tanita electrical impedance scale (Tanita BC-573 - Tanita Health equipment HK Limited, Tokyo, Japan; weight and body fat percentage (kg)). The waist circumference of the study

participants was measured in the standing position at the level of the umbilicus using a measuring tape. An automatic blood pressure monitor (HEM-7124 IN) was used to measure the systolic and diastolic blood pressure of the study participants. However, before recording the HRV, blood pressure was measured twice and the average of the two measurements was taken for analysis (Table 1).

Measurement of heart rate variability (HRV)

A quiet room with a temperature maintained between 22 °C and 24 °C was used to record HRV. Participants were familiarised with the laboratory procedures, thus ensuring that they remained completely relaxed during the recording phase. The participants remained in supine position for 20 minutes to allow relaxation. HRV was measured with a sampling rate of 1024 Hz using the lead II electrocardiogram signal transmitted via an analogue digital converter (Power Lab, AD Instruments Pty. Ltd., New South Wales, Australia). HRV was recorded for 15 min and the 5-min artifact-free section was analysed to obtain HRV time and frequency domain parameters using the HRV V8 Analysis Software (Power Lab; AD Instruments). All recordings were performed between 8 am and 11 am. The HRV measurement procedure was conducted as per standard protocol.[16] The time and frequency domain variables, that is, frequencies between 0.04 and 0.4 Hz, which are considered physiologically significant, were recorded.[16] The HRV variables recorded and analysed in the study were as follows: under the time domain—1) standard deviation of the R–R interval (SDNN), 2) root mean square of the successive difference in R–R interval (RMSSD), and 3) a percentage of successive RR intervals that differ by more than 50 ms (pNN50); under the frequency domain—1) Very low frequency (VLF), 2) low frequency (LF), 3) high frequency (HF), and 4) the LF/HF ratio.

Measurement of physical activity (PA) level

PA was assessed using the WHO Global Physical Activity Questionnaire (GPAQ) version 2.1, consisting of 16 questions that capture PA performed across various domains such as work, transport, recreation, and leisure. The GPAQ has been traditionally designed as an interviewer-administered method and been used across different populations to assess PA profiles of individuals. It has been revalidated among the Asian and European adult populations with a varying sample size ranging from 43 to 2657 across a vast age range (from 1579 years).[17] Its short-term test-retest reliability (10 days) ranges from 0.83 to 0.96 and its long-term reliability (three months) ranges from 0.53 to 0.83.[18] However, self-administration of the GPAQ has also been accepted and reported. A study comparing the GPAQ self-versus interviewer-based administration observed fair-to-moderate correlation for moderate-to-vigorous PA (MVPA) in self-administration (r = 0.30) and interviewer-administration (r = 0.46).[19]

In the present study, the English language GPAQ was used as a self-administered tool. The participants self-reported their involvement across these domains, and the final scores were manually calculated by the study investigators. The GPAQ is reported to be a suitable and acceptable instrument for PA assessment.[20]

Measurement of cardiorespiratory fitness (CRF)

The Bruce Protocol with motorised Treadmill (Runner 7410, Runner Srl - Via G. di Vittorio, 391−41032, Cavezzo (MO), Italy) was used to evaluate CRF, and the volume of oxygen uptake (VO2 max) was computed using a regression equation for men and women.[21] The test termination criteria were considered as per standard protocol.[22] The present study discusses CRF in terms of the VO2 peak only.

Statistical analysis

Statistical Package for the Social Sciences (SPSS) version 15.0, was used to compile and analyse the data (Version 15, Released 2006; SPSS for Windows, Version 15, SPSS, Inc., Chicago, IL, USA). The sample size was calculated with an estimation of 45 (Zα = 1.96, Zβ = 0.80, and an anticipated correlation of 0.4). Descriptive statistics were used to describe demographic characteristics. Data are presented as mean ± SD for continues variables and n (%) for categorical variables. Data were analysed using the Shapiro−Wilk test to assess if they were normally distributed. All HRV variables were log-transformed to normalize the distribution of skewed variables. Correlation tests were performed using either Pearson product-moment or Spearman rank correlation coefficients based on the distribution of data to determine the correlation between PA, CRF and HRV. A *p*-value < 0.05, was considered significant.

Results

Of the 45 participants, 23 men and 22 women took part in this study and were deemed overweight based on BMI cut-offs above 25 and below 30. All participants completed the tests and no adverse events were noted during the exercise test. Figure 1 shows the recruitment of the study participants. Table 1 describes the characteristics of the study participants, where the mean age was 22.5 ± 1.58 years, weight was 75.92 ± 8.99 kg, and body fat percentage was 30.6 ± 6.06%. Table 2 displays the characteristics of the HRV variables for the study groups, absolute values, and log-transformed values. No correlation were found between PA and any variable of HRV, as shown in Table 3. No correlation were found between CRF and any variable of HRV, as shown in Table 4. The study found that neither PA nor CRF had any significant correlation with any of the time or frequency domains of HRV. Furthermore, no significant associations were found between HRV and heart rate recovery in 1 min (HRR1), waist circumference, or body fat percentage.
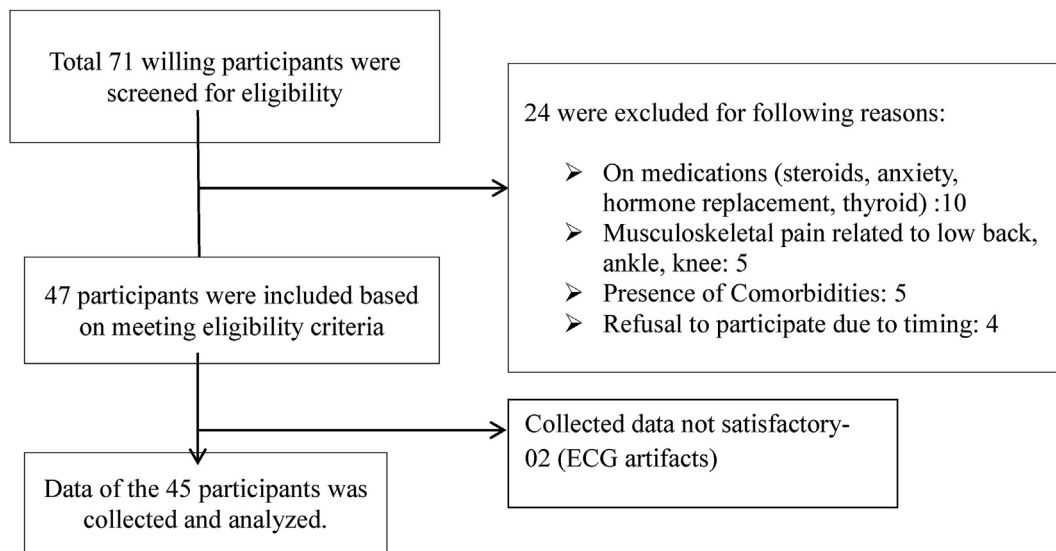
Total 71 willing participants were screened for eligibility

24 were excluded for following reasons:

➢ On medications (steroids, anxiety, hormone replacement, thyroid) :10
➢ Musculoskeletal pain related to low back, ankle, knee: 5
➢ Presence of Comorbidities: 5
➢ Refusal to participate due to timing: 4

47 participants were included based on meeting eligibility criteria

Collected data not satisfactory- 02 (ECG artifacts)

Data of the 45 participants was collected and analyzed.

Figure 1: Diagram of the flow of selection and continuity of study participants.

Table 1: Demographic characteristics of study population (n = 45 (men = 23; women = 22)).

Character	Mean ± SD/Median [IQR]
Age (Years)	22.53 ± 1.58
BMI (kg/m2)	27.38 ± 1.51
SBP (mm Hg)	117.42 ± 8.88
DBP (mm Hg)	74.08 ± 6.86
RHR (beats per minute)	78.82 ± 8.17
VO2 peak (ml/kg/min)	46.55 ± 7.59
METs min per week	900 [560,2400]
WC(cms)	86.55 ± 6.44
WHR	0.80 ± 0.05
WHtR	0.51 ± 0.02
BFP (%)	30.57 ± 6.06

Abbreviations: Body mass index (BMI), Body fat percentage (BFP%), Diastolic blood pressure(DBP), Metabolic equivalent (METs), Resting heart rate (RHR), Systolic blood pressure(SBP), Volume of peak oxygen uptake (VO2 peak), Waist circumference (WC), Waist Hip Ratio (WHR), Waist to Height Ratio (WHtR).

Table 3: Correlation between physical activity and heart rate variability.

HRV Variables	Male		Female	
	r	p value	r	p value
SDNN	0.06	0.76	0.07	0.73
RMSSD	0.08	0.71	0.10	0.64
PNN50	0.02	0.90	0.11	0.61
Total Power	0.008	0.97	0.03	0.87
VLF	0.010	0.96	0.01	0.96
LF (ms2)	0.011	0.96	0.11	0.60
HF (ms2)	0.005	0.98	0.16	0.47
LF/HF ratio	0.10	0.64	0.24	0.26

Abbreviations: Frequency domain variables of Heart rate variability: VLF- Absolute power of the very-low-frequency band (0.0033−0.04 Hz)− milli-second square, LF - Power in the low-frequency range (0·04−0·15 Hz), HF - Power in the high-frequency range (0·15−0·4 Hz), LF/HF ratio -Ratio of LF $[ms^2]$/HF $[ms^2]$.
Time-domain variables of HRV: SDNN- Standard deviation of NN intervals(ms), RMSSD- Root mean square of successive RR interval differences(ms), pNN50- Percentage of successive RR intervals that differ by more than 50 ms (%).

Table 2: Characteristics of heart rate variability variables, both absolute and log transformed values, of the study participants.

HRV Variables	Absolute values Median (IQR)	Log Transformed Mean ± SD/Median [IQR]
SDNN	60.27 (47.56, 81.54)	1.77 ± 0.16
RMSSD	46.22 (35.85, 85.96)	1.70 ± 0.24
pNN50	26.97 (12.99, 44.59)	1.30 ± 0.47
Total power	3265.43 (2111.73, 7243.57)	3.52 ± 0.35
VLF (ms2)	1085.41 (610.98, 1879.44)	3.00 ± 0.37
LF (ms2)	1027.67 (560.64, 1707.54)	2.96 ± 0.36
HF (ms2)	891.82 (453.53, 2879.03)	3.00 ± 0.47
LF/HF ratio	0.90 (0.50, 1.55)	0.04 (0.29,0.19)

Abbreviations: Frequency domain variables of Heart rate variability: VLF- Absolute power of the very-low-frequency band (0.0033−0.04 Hz)− milli-second square, LF - Power in the low-frequency range (0·04−0·15 Hz), HF - Power in the high-frequency range (0·15−0·4 Hz), LF/HF ratio -Ratio of LF $[ms^2]$/HF $[ms^2]$.
Time-domain variables of HRV: SDNN- Standard deviation of NN intervals(ms), RMSSD- Root mean square of successive RR interval differences(ms), pNN50- Percentage of successive RR intervals that differ by more than 50 ms (%).

Table 4: Correlation between cardiorespiratory fitness and heart rate variability.

HRV Variables	Male		Female	
	r	p value	r	p value
SDNN	0.15	0.49	0.34	0.11
RMSSD	0.08	0.71	0.37	0.09
PNN50	0.14	0.52	0.34	0.12
Total Power	0.18	0.39	0.31	0.15
VLF	0.36	0.08	0.39	0.07
LF (ms2)	0.10	0.64	0.38	0.07
HF (ms2)	0.009	0.96	0.27	0.22
LF/HF ratio	0.04	0.82	0.01	0.93

Abbreviations: Frequency domain variables of Heart rate variability: VLF- Absolute power of the very-low-frequency band (0.0033−0.04 Hz)− milli-second square, LF - Power in the low-frequency range ($0\cdot04-0\cdot15$ Hz), HF - Power in the high-frequency range ($0\cdot15-0\cdot4$ Hz), LF/HF ratio -Ratio of LF $[ms^2]$/HF $[ms^2]$.

Time-domain variables of HRV: SDNN- Standard deviation of NN intervals(ms), RMSSD- Root mean square of successive RR interval differences(ms), pNN50- Percentage of successive RR intervals that differ by more than 50 ms (%).

Discussion

This study aimed to correlate the relationship between PA, CRF and heart rate variability among young overweight individuals. The study results showed that HRV variables were not correlated with PA or CRF. Furthermore, log transformation of HRV variables did not have any impact on the results of the study. A vast majority of the study participants were highly physically active on self-administered GPAQ, while only one-third reported being moderately physically active. The participants recruited in this study were predominantly students residing in the campus, who were involved in some or the other form of PA. This is suggestive of their minimal involvement in sedentary behaviour patterns, even though they were classified as overweight based on their BMI values. Our study highlights a clinically relevant observation that a higher skeletal muscle mass or bone density value, may also contribute to higher BMI scores suggesting overweight. This drawback of BMI could be a major factor contributing to our results, leading to a contrasting results from previous research in the same area.[14]

The self-administered PA assessment using the GPAQ showed no correlation with HRV, despite being a reliable method. The likelihood of overestimation/exaggeration of scores on self-administration is minimal as study participants understood the questionnaire and were very familiar with the language. Hence, the subjective assessment method of the PA assessment might not have influenced our study findings.

The study found no correlation between CRF and HRV among the participants. Previous studies of overweight individuals have reported a positive correlation between a few HRV indices and CRF, indicating greater autonomic regulation with a higher VO2 max. The VO2 max of most participants in this study (90%) belonged to a good category according to the ACSM's classification,[22] but the remaining few dropped below the fair level. All the research participants, during exercise test, met the full test requirement for termination. However, we found no correlation between CRF and any of the HRV indices.

The resting heart rate influences autonomic control, and a higher resting heart rate is indicative of reduced parasympathetic activity.[23−29] In the present study, the average resting heart rate of overweight individuals was 70 beats per minute. Also, CAF fluctuates throughout the day and varies according to different activities, the regulation of hormones and muscle mass in an individual. Assessment of these variables were not performed in the present study, which could have impacted our findings. Additionally, we did not assess factors such as diet, stress, and sleep patterns among the study participants as these may contribute to an altered HRV. Although speculative, the lack of significant correlation found in the present observational study may indicate the need to conduct a detailed evaluation of HRV by addressing all possible confounders.

The present study utilised existing and available resources in the study setting to conduct the study. However, for an objective assessment of PA, devices such as pedometers and accelerometers may be utilised in future research. Similarly, CRF may be assessed using the gold standard metabolic analyser to estimate the volume of oxygen uptake. HRV is influenced by several confounding factors such as sleep, diet, stress, anxiety, hormone levels, and metabolic biomarkers, which were not assessed in the present study. Furthermore, it may be interesting to explore gender-specific differences and associations on a larger sample size to undertand HRV in overweight individuals. Longitudinal studies among young overweight adults are needed to clarify the underlying relationship between PA, CRF, adiposity, and HRV by controlling for important confounders, and thereby targeting lifestyle interventions to address the public health burden of cardiometabolic diseases.

Conclusion

The study found no correlation between PA and CRF with heart rate variability among young overweight adults. Clinical assessment of HRV among individuals reporting physical inactivity may help in the early detection of cardiac autonomic dysfunction thereby enhance risk-prevention strategies.

Source of funding

Conflict of interest

The authors have no conflicts of interest to declare.

Ethical approval

The study was registered under the Clinical Trial Registry of India (CTRI/2018/04/013325) after receiving approval

from the Kasturba Medical College and Kasturba Hospital Institutional Ethics Committee (IEC 90/2018) and approval was issued on 14.02.2018. All participants provided informed consent prior to enrolment in the study. This observational cross-sectional study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines and the Declaration of Helsinki.

Authors contributions

MN, MKS, AB, and VK conceptualised and designed the study protocol. MN contributed to the data collection for this study. The data were analysed, and findings were interpreted by MN, MKS, AB, and VK. A preliminary draft of the manuscript was prepared by MN. The manuscript was critically curated for its scientific content and relevance by MKS, AB, and VK. The final version of the manuscript was read and approved by all the authors prior to journal submission. All authors have met the recommended criteria by ICMJE for authorship and have contributed effectively to this manuscript. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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