

A Comparative Study of Anthropometry and Heart Rate Variability in Normotensive Offspring of Diabetic Parents and Offspring of Non-Diabetic Parents

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Abstract

Background: A parental history of type 2 diabetes mellitus (T2DM) may be associated with early alterations in body composition and cardiac autonomic regulation before the development of overt diabetes. This study compared Anthropometric parameters and heart rate variability (HRV) between normotensive, non-diabetic offspring of diabetic parents and offspring of non-diabetic parents.

Methods: This cross-sectional comparative study included 70 age- and sex-matched normotensive, non-diabetic participants, comprising 35 offspring of diabetic parents (cases) and 35 offspring of non-diabetic parents (controls). Anthropometric parameters included body mass index (BMI)kg/(m²), waist-hip ratio, thigh circumference(cms), waist circumference(cms)and body-fat percentage. frequency domain parameters [LF power in normalized units (LFnu), HF power in normalized units (HFnu), LF/HF ratio, total power (TP (ms²)), absolute LF power (ms²), and absolute HF power((ms²)] & time domain parameters (mean RR interval(ms), SDRR (ms), and RMSSD (ms)], of HRV was assessed using lead-II ECG. HRV & Anthropometric parameters between two groups were assessed using an unpaired *t*-test, and Pearson's correlation was used to examine association between Anthropometric and HRV parameters.

Results: offsprings of diabetic parents had significantly higher BMI (23.3 ± 2.2 vs. 22.1 ± 2.4 kg/m², $p = 0.035$), waist-hip ratio (0.90 ± 0.02 vs. 0.86 ± 0.04 , $p = 0.004$), and thigh circumference (51.6 ± 4.4 vs. 48.69 ± 4.6 cm, $p = 0.008$). LF power in normalized units was significantly higher in cases (49.2 ± 12.9 vs. 41.5 ± 14.38 , $p = 0.021$), while other HRV indices did not differ significantly. BMI correlated positively with LF (nu) and LF/HF ratio and negatively with HF (nu), heart rate(bpm), and mean RR (ms).

Conclusion: Offspring of diabetic parents demonstrated differences in selected Anthropometric measures and LF (nu), with BMI kg/m²showing multiple associations with HRV.

Keywords: Heart Rate Variability, Type 2 Diabetes Mellitus, Anthropometry.

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Introduction

Type 2 diabetes mellitus (T2DM) is a major metabolic disorder characterized by insulin resistance and progressive impairment of pancreatic β -cell function. The development of T2DM is influenced by a complex interaction between genetic predisposition, environmental factors, lifestyle, and body composition. A positive family history of T2DM is an important risk factor for the development of the disease, and individuals with diabetic parents may exhibit metabolic and physiological alterations even before the onset of

clinically apparent diabetes. Identification of early markers of altered cardiovascular and metabolic function in apparently healthy offspring of individuals with T2DM may therefore provide an opportunity for early risk characterization and preventive intervention. Cardiac autonomic regulation can be assessed non-invasively using heart rate variability (HRV), which reflects beat-to-beat variation in cardiac cycle length. HRV is influenced by the interaction between sympathetic and parasympathetic components of the autonomic

nervous system and provides information regarding cardiovascular autonomic modulation. Both time-domain and frequency-domain measures of HRV are used for this purpose. Time-domain indices such as the standard deviation of normal-to-normal intervals (SDRR) and the root mean square of successive differences (RMSSD) provide information regarding overall and short-term beat-to-beat variability, respectively. Frequency-domain indices include low-frequency power (LF) and high-frequency power (HF), expressed either in absolute units (ms^2) or normalized units (nu), together with total power (TP) and the LF/HF ratio. Alterations in these measures may occur before clinically evident cardiovascular or metabolic disease.

Individuals with a parental history of T2DM have been investigated for evidence of early cardiac autonomic alterations, although the findings have not been consistent. Tamilselvan et al. studied HRV among non-diabetic offspring of individuals with T2DM and reported differences in autonomic function, suggesting that cardiovascular autonomic alterations may be detectable before the development of diabetes.[1] Similarly, Pokhrel et al. reported differences in HRV among healthy offspring with a parental history of T2DM.[2] These observations raise the possibility that familial susceptibility to T2DM may be associated with early alterations in cardiovascular autonomic regulation.

However, evidence from other studies suggests that autonomic function may remain preserved in metabolically healthy offspring. Bajaj et al. evaluated HRV in healthy offspring with a parental history of T2DM, while Neves et al. investigated first-degree relatives of individuals with T2DM without metabolic disorders. Their findings did not demonstrate consistent impairment of HRV across all measures.[3,4] Goel et al. also reported no statistically significant differences in cardiovascular parasympathetic function tests among offspring of individuals with T2DM.[5] These apparently contrasting findings indicate that the relationship between parental history of T2DM and cardiovascular autonomic function may be complex and may be influenced by age, metabolic status, body composition, lifestyle, and the specific autonomic parameters assessed. Anthropometric characteristics are also relevant in the context of familial risk for T2DM. Increased BMI and altered body-fat distribution are important risk factors for metabolic dysfunction and may be associated with changes in cardiovascular autonomic regulation. Padaki et al. reported differences in Anthropometric characteristics, including BMI and waist-hip ratio, among individuals with a family history of T2DM.[6] Such findings suggest that alterations in body composition may be present in apparently healthy individuals with familial susceptibility to

diabetes before the development of overt metabolic disease.

Body mass index (BMI) provides a commonly used measure of body size but does not directly distinguish fat mass from lean mass. Deurenberg et al. demonstrated that the relationship between BMI and body-fat percentage varies according to age and sex, emphasizing the importance of considering additional Anthropometric measures when assessing adiposity.[7] Measures such as waist circumference, hip circumference, waist-hip ratio, thigh circumference, and body-fat percentage may provide complementary information regarding overall and regional body composition. These measures may also be relevant when investigating their potential relationship with cardiovascular autonomic modulation.

The possible interaction between body composition and autonomic function is particularly relevant in individuals with familial susceptibility to T2DM. Increased adiposity and altered fat distribution may be accompanied by changes in cardiovascular regulation, while autonomic alterations may potentially represent an early physiological characteristic associated with future metabolic risk. Nevertheless, studies simultaneously examining multiple HRV indices and detailed Anthropometric characteristics in healthy offspring of diabetic parents remain limited, and the relationship between individual Anthropometric measures and specific HRV parameters has not been fully established.

Therefore, a comparative assessment of HRV and Anthropometric characteristics in offspring of individuals with T2DM and offspring of non-diabetic individuals may help clarify whether differences in cardiovascular autonomic modulation and body composition are detectable before the development of diabetes. Furthermore, examining correlations between HRV indices and Anthropometric parameters may provide additional information regarding the relationship between body composition and cardiac autonomic regulation. The present study was therefore undertaken to compare cardiac autonomic function, assessed using frequency-domain HRV parameters [LF power in normalized units (LFnu), HF power in normalized units (HFnu), LF/HF ratio, total power (ms^2), absolute LF power (ms^2), and absolute HF power(ms^2) and time-domain parameters mean RR interval (ms), SDRR (ms), and RMSSD (ms), between offspring of individuals with T2DM and offspring of non-diabetic individuals. The study also aimed to compare Anthropometric characteristics, including BMI, waist circumference, hip circumference, waist-hip ratio, thigh circumference, and body-fat percentage, between the two groups and to determine the correlations between HRV parameters and Anthropometric measures.

We hypothesized that offspring of individuals with T2DM may demonstrate differences in selected HRV and Anthropometric parameters compared with offspring of non-diabetic individuals, and that variations in Anthropometric characteristics may be associated with differences in cardiac autonomic modulation.

Methodology

After obtaining approval and clearance from the Institutional Ethics Committee, written informed consent was obtained from all participants. The present cross-sectional study was conducted among 35 normotensive, non-diabetic male and female subjects with a parental history of diabetes mellitus involving either the father, mother, or both. An age- and sex-matched group of 35 normotensive, non-diabetic subjects without a parental history of diabetes mellitus was recruited from the general population of Karwar. The sample size was calculated based on the results of a previous study. [4]

Subjects with cardiovascular disorders and those taking medications that could affect glucose homeostasis or the cardiovascular, respiratory, or haematological systems were excluded from the study.

The health status of the study participants was assessed through history taking and clinical examination. Anthropometric parameters were measured using standardized procedures. Weight was measured using a calibrated weighing machine with participants wearing light clothing and no footwear. Height was measured in centimetres using a measuring scale fixed to the wall. Body mass index

was calculated as body weight in kilograms divided by height in meters squared (kg/m^2). Waist circumference, hip circumference, and thigh circumference were measured using standard Anthropometric techniques. Body-fat percentage was estimated using the Deurenberg equation. [7]

Participants were instructed to arrive 15 minutes before the recording to become familiarized with the laboratory environment. They were advised to avoid strenuous exercise on the day of testing and to avoid a heavy meal and coffee for at least 2 hours before the assessment. Random blood glucose levels were assessed using an Accu-Chek Active glucometer. Blood pressure was recorded in the supine position after 5 minutes of rest.

HRV was recorded using a Lead-II ECG in a temperature-controlled room maintained at 20–24°C. ECG signals were acquired and analyzed using Lab Chart software and AD Instruments equipment in the Department of Physiology. Time-domain and frequency-domain HRV parameters were recorded.

Statistical Analysis: The collected data were compiled in Microsoft Excel and expressed as mean $\pm$ standard deviation (SD). Anthropometric and HRV parameters were compared between the two groups using an unpaired *t* test. Pearson's correlation coefficient was used to assess the relationship between Anthropometric parameters and HRV indices. A *p* value <0.05 was considered statistically significant.

Results

Table 1: Vital Parameters Between Offspring of Diabetics and Offspring of Non- Diabetics

Study parameters		Mean $\pm$ Sd	Unpaired 't'	p-value
Pulse(bpm)	Case	82 $\pm$ 9	1.525	0.133
	Control	79 $\pm$ 5		
SBP (mmHg)	Case	113 $\pm$ 6	1.282	0.204
	Control	111 $\pm$ 6		
DBP(mmHg)	Case	77 $\pm$ 4	0.897	0.373
	Control	76 $\pm$ 3		
Respiratory rate(cpm)	Case	20 $\pm$ 1	0.256	0.799
	Control	19 $\pm$ 1		
RBS(mg/dl)	Case	107 $\pm$ 22	0.027	0.979
	Control	107 $\pm$ 13		
*Significant difference at $p \leq 0.05$ * cases- offspring of diabetics, controls- offspring of Non-diabetics *SD- standard deviation				

Table 2: Anthropometric Parameters Between Offspring of Diabetics and Offspring of Non- Diabetics

Study parameters		Mean $\pm$ Sd	Unpaired 't'	p-value
Age(yrs)	Case	19.8 $\pm$ 1.2	0.766	0.446
	Control	19.6 $\pm$ 0.9		
BMI(kg/meter ²)	Case	23.3 $\pm$ 2.2	2.155	0.035*
	Control	22.1 $\pm$ 2.4		
Waist Circumference(cm)	Case	79.09 $\pm$ 7.1	1.29	0.2
	Control	76.89 $\pm$ 7.23		
Waist-Hip ratio	Case	0.9 $\pm$ 0.02	3.013	0.004*
	Control	0.86 $\pm$ 0.04		
Thigh circumference(cms)	Case	51.6 $\pm$ 4.4	2.714	0.008*
	Control	48.69 $\pm$ 4.6		
Bodyfat %	Case	20.12 $\pm$ 4.9	1.186	0.24
	Control	18.53 $\pm$ 6.3		
*Significant difference at $p \leq 0.05$ * cases- offspring of diabetics, controls- offspring of non-diabetics SD-standard deviation				

Statistically significant differences were observed between offsprings of diabetics & offsprings of non-diabetics with respect to BMI ($p = 0.035$), waist–hip ratio ($p = 0.004$), and thigh circumference ($p = 0.008$). The offsprings of diabetics had higher mean values for all three parameters. Whereas no statistically significant differences were observed for age ($p = 0.446$), waist circumference ($p = 0.20$), or body fat percentage ($p = 0.24$).

Table 3: Gender Wise Distribution of Offspring of Diabetics and Offspring of Non- Diabetics

Gender	Case (35)	Control (35)	Chi-square	p-value
Female	17	17	0.0001	1.000
Male	18	18		

The gender distribution was identical between the case group (offspring of individuals with diabetes) and the control group (offspring of non-diabetic individuals), with 17 females and 18 males in each group. There was no statistically significant difference in gender distribution between the groups ($\chi^2 = 0.0001$, $p = 1.000$).

Table 4: Heart Rate Variability Parameters Between Offspring of Diabetics and Offspring of Non- Diabetics

Study parameters		Mean ± Sd	Unpaired 't'	p-value
Average Beats (BPM)	Case	78.59 ± 5.36	1.351	0.181
	Control	76.63 ± 6.72		
LF Power (nu)	Case	49.2 ± 12.9	2.369	0.021 *
	Control	41.5 ± 14.38		
HF Power (nu)	Case	50.26 ± 14.71	1.36	0.178
	Control	54.89 ± 13.74		
LF/Hf ratio	Case	1.01 ± 0.63	0.196	0.845
	Control	0.97 ± 1.01		
Total Power (ms²)	Case	2127.1 ± 1246.52	0.786	0.434
	Control	2376.99 ± 1407.17		
LF Power (ms²)	Case	682.97 ± 533.18	0.26	0.796
	Control	713.67 ± 451.67		
HF Power (ms²)	Case	738.2 ± 622.98	1.062	0.292
	Control	884.39 ± 524.05		
Average RR (ms)	Case	782.5 ± 59.4	1.248	0.216
	Control	763.3 ± 69.1		
SDRR (ms)	Case	44.30 ± 12.96	0.947	0.347
	Control	47.22 ± 12.81		
RMSSD (ms)	Case	42.28 ± 11.55	1.499	0.139
	Control	47.42 ± 16.69		
*Significant difference at p ≤ 0.05 * cases- offspring of Diabetics, controls- offspring of Non-diabetics * SD-Standard deviation				

Comparison of heart rate variability parameters between offspring of diabetics and offspring of non-diabetics revealed a statistically significant

difference in LF Power expressed in normalized units ($p = 0.021$). LF Power was significantly higher in offspring of diabetics (49.2 $\pm$ 12.9 nu) compared

with offspring of non-diabetics (41.5 ± 14.38 nu). However, no statistically significant differences were observed between the two groups with respect to average heart rate, HF Power (nu), LF/HF ratio, total power, LF Power (ms^2), HF Power (ms^2),

average RR interval(ms), SDRR, or RMSSD (ms) ($p > 0.05$). These findings indicate that, among the HRV parameters studied, LF Power (nu) was the only parameter that differed significantly between offspring of diabetics and offspring of non-diabetics.

Table 5: Co-Relation of Anthropometric Parameters with HRV in Offspring of Diabetics

Anthropometric parameters	R & p value	HRV Parameters									
		Heart rate (bpm)	LF Power (nu)	HF Power (nu)	LF/HF Ratio	Total Power (ms^2)	LF Power (ms^2)	HF Power (ms^2)	Average RR (ms)	SDRR (ms)	RMSSD (ms)
Height (cms)	r	-0.02	-0.06	0.04	0.03	0.02	0.14	-0.06	0.05	-0.16	-0.18
	p-value	0.91	0.72	0.83	0.88	0.92	0.43	0.72	0.79	0.36	0.29
Weight (kgs)	r	-0.36	0.33	-0.26	0.29	0.11	0.27	-0.09	-0.29	0.17	0.00
	p-value	0.032*	0.05	0.13	0.09	0.54	0.12	0.60	0.09	0.34	1.00
BMI (kg/m^2)	r	-0.48	0.51	-0.38	0.35	0.11	0.21	-0.07	-0.44	0.37	0.17
	p-value	0.004*	0.002*	0.023*	0.04*	0.55	0.23	0.70	0.008*	0.028*	0.33
Waist (cms)	r	-0.03	0.22	-0.17	0.37	-0.20	-0.13	-0.19	0.01	-0.20	-0.27
	p-value	0.85	0.20	0.33	0.029*	0.25	0.46	0.28	0.96	0.24	0.12
Hip (cms)	r	0.05	0.18	-0.14	0.35	-0.24	-0.16	-0.21	0.06	-0.20	-0.27
	p-value	0.78	0.30	0.42	0.04*	0.17	0.35	0.24	0.72	0.26	0.12
Waist-Hip ratio	r	-0.35	0.18	-0.13	0.09	0.16	0.16	0.08	-0.22	-0.02	0.01
	p-value	0.037*	0.29	0.46	0.61	0.34	0.36	0.65	0.20	0.91	0.94
Thigh circumference (cms)	r	-0.22	0.30	-0.27	0.40	-0.12	0.05	-0.24	-0.12	0.00	-0.22
	p-value	0.21	0.08	0.12	0.018*	0.49	0.77	0.17	0.48	0.99	0.21
Bodyfat%	r	0.13	0.09	-0.10	0.14	0.22	0.11	0.18	0.09	0.07	0.18
	p-value	0.45	0.62	0.58	0.41	0.21	0.53	0.30	0.62	0.68	0.31

*Significant correlation at $p \leq 0.05$, r - Pearson's correlation coefficient

Pearson's correlation analysis was performed to examine the linear associations between Anthropometric and heart rate variability (HRV) parameters in offsprings of diabetes mellitus. Height was not significantly correlated with any of the cardiovascular or HRV parameters assessed (all $p > 0.05$). Body weight showed a significant negative correlation with heart rate ($r = -0.36$, $p = 0.032$). No, statistically significant correlations were observed between body weight and the remaining HRV parameters.

BMI demonstrated the greatest number of significant associations with cardiovascular and HRV measures. BMI was negatively correlated with heart rate ($r = -0.48$, $p = 0.004$), HF power in normalized units ($r = -0.38$, $p = 0.023$), and average RR interval ($r = -0.44$, $p = 0.008$). In contrast, BMI showed positive correlations with LF power in normalized units ($r = 0.51$, $p = 0.002$), LF/HF ratio ($r = 0.35$, $p = 0.040$), and SDRR ($r = 0.37$, $p = 0.028$). BMI was not significantly correlated with total power, absolute LF power, absolute HF power, or RMSSD. Among the measures of body circumferences, waist circumference was positively correlated with LF/HF ratio ($r = 0.37$, $p = 0.029$). Similarly, hip circumference ($r = 0.35$, $p = 0.040$)

and thigh circumference ($r = 0.40$, $p = 0.018$) showed significant positive correlations with LF/HF ratio.

Waist-hip ratio was negatively correlated with heart rate ($r = -0.35$, $p = 0.037$), while no significant correlations were observed between waist-hip ratio and the other HRV parameters. Body-fat percentage was not significantly correlated with heart rate or any of the HRV parameters (all $p > 0.05$). However, no association was found between anthropometry and HRV parameters in offspring of non-diabetics

Discussion

The present study compared Anthropometric characteristics and heart rate variability (HRV) between normotensive, non-diabetic offspring of parents with type 2 diabetes mellitus (T2DM) and age- and sex-matched offspring of non-diabetic parents. The principal findings were that offspring of diabetic parents had significantly higher BMI, waist-hip ratio, and thigh circumference than controls. Among the HRV parameters, LF power expressed in normalized units (LFnu) was significantly higher in the offspring of diabetic parents, whereas HFnu, LF/HF ratio, total power, absolute LF power, absolute HF power, mean RR

interval, SDRR, and RMSSD did not differ significantly between groups. Pearson's correlation analysis further demonstrated significant associations between BMI and several HRV parameters, while waist, hip, and thigh circumferences showed significant positive correlations with LF/HF ratio.

The significantly higher BMI observed among offspring of diabetic parents indicates that differences in Anthropometric characteristics may be detectable even in young individuals who are normotensive and non-diabetic. This finding is consistent with the observations of Padaki et al., who reported differences in Anthropometric characteristics among individuals with a family history of T2DM, including higher BMI and waist-hip ratio compared with controls. [6] The higher waist-hip ratio observed in the present study may indicate differences in body-fat distribution between the groups, even in the absence of established diabetes.

The significantly greater thigh circumference in the offspring of diabetic parents is also noteworthy. Although regional Anthropometric measurements are less commonly investigated than BMI or waist circumference, their inclusion may provide additional information about body composition and body-fat distribution. Padaki et al. similarly incorporated thigh circumference and other segmental measurements in their assessment of individuals with a family history of T2DM. [6] The present findings therefore support the importance of evaluating multiple Anthropometric dimensions rather than relying exclusively on BMI when investigating individuals with familial susceptibility to diabetes.

In contrast, body-fat percentage did not differ significantly between the two groups in the present study. This finding highlights the distinction between BMI and estimated body composition. BMI is a measure of body size rather than a direct measure of adipose tissue. Deurenberg et al. demonstrated that the relationship between BMI and body-fat percentage varies according to age and sex and developed prediction equations incorporating these variables. [7] Therefore, the higher BMI observed in the present study should not necessarily be interpreted as indicating a corresponding difference in total body-fat percentage.

Heart Rate Variability in Offspring of Diabetic Parents: The principal HRV finding was a significantly higher LFnu in offspring of diabetic parents compared with offspring of non-diabetic parents. However, there were no significant differences in HFnu, LF/HF ratio, total power, absolute LF power, absolute HF power, SDRR, or RMSSD. Thus, the present findings suggest a

difference in one frequency-domain HRV measure rather than generalized impairment of HRV.

Previous studies have reported variable findings regarding HRV in healthy offspring of individuals with T2DM. Tamilselvan et al. investigated HRV in non-diabetic offspring of parents with T2DM and reported differences in cardiac autonomic regulation, suggesting that autonomic alterations may be detectable before the development of overt diabetes. [1] Pokhrel et al. similarly reported differences in HRV among healthy offspring with a parental history of T2DM. [2] These findings support the possibility that familial susceptibility to T2DM may be associated with early alterations in cardiovascular autonomic regulation.

The present findings, however, differ from some aspects of the observations reported by Bajaj et al. In their study of healthy offspring with a parental history of diabetes, the authors did not observe significant differences in several HRV parameters between offspring with and without parental diabetes. [3] The absence of a significant difference in LF/HF ratio in the present study is therefore compatible with the observation that parental history alone does not necessarily result in a uniform alteration across all HRV indices.

Neves et al. investigated first-degree relatives of individuals with T2DM who did not have metabolic disorders and reported preserved HRV in this population. [4] Their findings suggest that HRV may remain relatively preserved in metabolically healthy relatives, despite the presence of familial risk. This observation is particularly relevant to the present study because the participants were normotensive and non-diabetic, and most HRV parameters did not differ significantly between groups. Dias-Filho et al. reported differences in several HRV indices among adolescents with a family history of diabetes, including measures of global and parasympathetic autonomic modulation. [8] The differences between their findings and those of the present study may partly reflect differences in age, study population, HRV methodology, and participant characteristics. Their study involved adolescents, whereas the present study included young adults. In addition, the present study specifically included normotensive and non-diabetic participants, potentially reducing the magnitude of metabolic or cardiovascular differences between groups.

Goel et al. evaluated cardiovascular parasympathetic function in offspring of individuals with T2DM and reported no statistically significant differences in parasympathetic function tests between offspring of diabetic and non-diabetic parents. [5] The absence of a significant difference in RMSSD in the present study is compatible with these findings and suggests that parasympathetic-related indices may remain

relatively preserved in some young, metabolically healthy offspring despite familial risk.

Taken together, the available evidence indicates that the relationship between parental history of T2DM and HRV is not uniform. Some studies have reported alterations in autonomic modulation. [1,2,8] whereas others have reported preserved or limited autonomic alterations in healthy offspring. [3,5] Differences in age, sex, body composition, physical activity, metabolic status, sample size, HRV recording conditions, and the specific HRV variables assessed may contribute to these variations.

Relationship Between Anthropometry and HRV:

An important finding of the present study was the relationship between BMI and multiple HRV parameters. BMI demonstrated a moderate positive correlation with LFnu ($r = 0.51, p = 0.002$), which was the strongest correlation observed. BMI was also positively correlated with LF/HF ratio ($r = 0.35, p = 0.040$) and SDRR ($r = 0.37, p = 0.028$). Conversely, BMI showed significant negative correlations with heart rate ($r = -0.48, p = 0.004$), HFnu ($r = -0.38, p = 0.023$), and mean RR interval ($r = -0.44, p = 0.008$).

These findings suggest that variation in BMI within the study population was associated with several aspects of cardiac beat-to-beat variability and frequency-domain HRV. The positive association between BMI and LFnu, together with the negative association between BMI and HFnu, indicates a change in the relative distribution of spectral HRV components with increasing BMI. The positive association between BMI and LF/HF ratio is also consistent with this pattern. Nevertheless, these findings should be interpreted cautiously. LFnu and LF/HF should not be regarded as direct or specific measures of sympathetic activity. HRV spectral components are influenced by several physiological and methodological factors. Therefore, the present results are more appropriately described as associations between BMI and frequency-domain HRV characteristics rather than evidence of definite sympathetic overactivity or sympathovagal imbalance.

The relationship between BMI and HRV is particularly relevant because BMI was significantly higher in the offspring of diabetic parents than in controls. Thus, the group difference in LFnu may coexist with, or be partly related to, differences in Anthropometric characteristics. Neves et al. similarly demonstrated that HRV findings in first-degree relatives of individuals with T2DM should be considered in the context of metabolic and Anthropometric characteristics.[4] The present correlation findings therefore emphasize the importance of considering body composition when

interpreting HRV differences associated with familial diabetes risk.

Waist circumference, hip circumference, and thigh circumference were also positively correlated with LF/HF ratio. Waist circumference showed a significant correlation with LF/HF ($r = 0.37, p = 0.029$), as did hip circumference ($r = 0.35, p = 0.040$) and thigh circumference ($r = 0.40, p = 0.018$). These findings suggest that regional Anthropometric characteristics may be associated with frequency-domain HRV. However, these measurements are physiologically interrelated, and the present bivariate correlations cannot establish whether any one Anthropometric measure has an independent relationship with LF/HF.

Waist-hip ratio was significantly and negatively correlated with heart rate ($r = -0.35, p = 0.037$), although it was not significantly correlated with the other HRV measures. This finding is relevant because waist-hip ratio was also significantly higher in the offspring of diabetic parents. Padaki et al. similarly reported differences in waist-hip ratio among individuals with a family history of T2DM. [6] Together, these observations suggest that differences in body-fat distribution may be present in individuals with familial susceptibility to diabetes and may be associated with selected cardiovascular measures.

BMI and Body-Fat Percentage: An interesting finding was the absence of significant correlations between body-fat percentage and HRV despite the multiple associations observed with BMI. This may reflect differences between BMI and estimated body composition as measures of adiposity. Deurenberg et al. demonstrated that BMI can be used to estimate body-fat percentage when age and sex are incorporated into prediction equations but also emphasized the influence of these variables on the BMI-body-fat relationship.[7]

Therefore, the significant relationship between BMI and HRV in the present study should not automatically be interpreted as an effect of adipose tissue itself. BMI incorporates both fat mass and lean body mass and may reflect broader differences in body size or composition. The absence of significant associations between body-fat percentage and HRV further suggests that the relationship between anthropometry and cardiac autonomic modulation may not be explained solely by total body fat.

Interpretation in Relation to Familial Risk of T2DM: The combined findings of the present study suggest that young, normotensive, non-diabetic offspring of diabetic parents may exhibit differences in selected Anthropometric and HRV characteristics before the development of clinically apparent T2DM. The higher BMI, waist-hip ratio, and thigh

circumference in the offspring of diabetic parents indicate differences in body habitus, while the higher LFnu suggests a difference in one component of frequency-domain HRV.

However, the absence of significant differences in LF/HF ratio, HFnu, total power, absolute LF and HF power, SDRR, and RMSSD indicates that the observed HRV findings do not represent a generalized reduction in HRV. This interpretation is consistent with studies reporting preserved or limited autonomic alterations among metabolically healthy relatives of individuals with T2DM. [3,5]

The correlation analysis provides additional evidence that Anthropometric characteristics may be relevant when evaluating HRV in individuals with familial susceptibility to T2DM. In particular, BMI demonstrated the most extensive associations with HRV, while regional circumference measures were primarily associated with LF/HF ratio. These findings may help explain why studies examining family history alone have produced differing HRV results. Familial risk may coexist with differences in body composition and metabolic characteristics, which may in turn influence autonomic measurements.

Strengths: The study included age- and sex-matched normotensive, non-diabetic offspring with and without parental T2DM, allowing comparison before the development of overt metabolic disease. The simultaneous assessment of multiple time- and frequency-domain HRV indices and detailed Anthropometric parameters also enabled evaluation of their interrelationships.

Limitations: The relatively small sample size and cross-sectional design limit the generalizability of the findings and preclude causal inference. Potential confounding factors such as physical activity, dietary habits, and genetic and metabolic characteristics were not comprehensively assessed. In addition, body-fat percentage was estimated rather than directly measured.

Conclusion

Young, normotensive, non-diabetic offspring of individuals with T2DM demonstrated higher BMI, waist-hip ratio, thigh circumference, and LFnu compared with offspring of non-diabetic individuals. BMI was associated with several HRV parameters, suggesting a relationship between Anthropometric characteristics and cardiac autonomic modulation. However, most HRV indices did not differ significantly between groups, indicating that familial T2DM risk may be

associated with selective rather than generalized alterations in autonomic function. Longitudinal studies with larger samples are warranted to determine the clinical significance of these findings.

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