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ORIGINAL ARTICLE

Exploring the diabesity characteristics and associated all-cause mortality at a population level: results from a small European island state

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Abstract

Aim Diabesity, the co-occurrence of diabetes and obesity, presents a global health crisis. Understanding its prevalence, associated risk factors, and mortality outcomes is crucial for effective public health interventions. This study aims to investigate the prevalence of diabesity and diabetes, assess associated risk factors, and analyze mortality outcomes over a 7-year period in the diabetogenic country of Malta.

Subject and methods A nationwide health examination survey (2014–16) was conducted involving 3947 adults aged 18–70 years. Sociodemographic data, anthropometric measurements, and blood samples were collected. Relationships between different adiposity indices were explored. Mortality data was obtained by cross-referencing with the national mortality register. Statistical analyses included chi-square tests, logistic regression, and Cox proportional hazard models.

Results Prevalence of obesity was 34.08%, diabetes 10.31%, and diabesity 5.78%. Sociodemographic characteristics were similar across all three cohorts. Multivariable regression identified increasing age (OR 1.10 CI95% 1.07–1.12; $p \leq 0.001$), male gender (OR 0.53 CI95% 0.30–0.93; $p = 0.03$), and low educational level (OR 2.19 CI95% 1.39–3.45; $p = 0.001$) as significant predictors of diabesity. Only diabetes showed a significant increase in mortality risk (HR 3.15 CI95% 1.31–7.62; $p = 0.02$) after adjustment, with gender (HR 3.17 CI95% 1.20–8.37) and body adiposity index (HR 1.08 CI95% 1.01–1.16) also significant ($p \leq 0.05$).

Conclusion Diabesity represents a substantial public health challenge in Malta, with implications for mortality outcomes. Targeted interventions addressing sociodemographic disparities and promoting healthy lifestyles are essential to mitigate its impact. The findings underscore the need for comprehensive healthcare strategies and policy initiatives to combat diabesity and reduce associated mortality rates.

Keywords Mortality · Obesity · Adiposity · Diabetes mellitus · Malta · Population health

Introduction

Diabesity, a portmanteau of diabetes and obesity, represents a growing epidemic worldwide. Both conditions are intricately linked, with obesity being a significant risk factor for developing type 2 diabetes mellitus (T2DM). The global prevalence of both diabetes and obesity has been steadily increasing over the past few decades, reaching alarming proportions (Ong et al. 2023; Phelps et al. 2024).

The International Diabetes Federation (IDF) approximated that at a global level, 537 million people were living with the disease during 2021 with associated healthcare expenditure projected to exceed $1 trillion by 2045 (Sun et al. 2022). According to the World Health Organization (WHO) in 2016 over 1.9 billion adults were overweight, of which, 650 million were obese, with the global-age standardized prevalence more than doubling between 1990 and 2022 (World Health Organization 2024a, b, 2008). The global annual cost of overweight and obesity statuses is expected to cost $4.32 trillion by 2035 (World Obesity 2023). Diabesity is thus a consequential healthcare burden, making it one of the most pressing public health challenges

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of the twenty-first century. Furthermore, the indirect costs of diabesity, including reduced workforce participation and premature mortality, impose significant economic burdens on societies worldwide (Okunogbe et al. 2021).

The COVID-19 pandemic has exacerbated the diabesity epidemic (Khunt et al. 2022). Individuals with diabetes and obesity are at higher risk of severe illness and mortality from COVID-19, underscoring the urgent need to address these underlying health conditions (Al-sabah et al. 2020). The pandemic disrupted routine healthcare services, leading to delays in diagnosis, treatment, and management of diabetes and obesity (Al-sabah et al. 2020). Additionally, lockdown measures resulted in sedentary lifestyles, unhealthy dietary habits, and increased stress, further contributing to the rise in diabesity cases (Ray et al. 2022; Khunti et al. 2022).

In light of the significant global diabesity epidemic, understanding the characteristics of diabesity at a population level is crucial for informing public health policies and interventions (Committee on Assuring the Health of the Public in the 21st Century 2022). By identifying high-risk populations and implementing targeted prevention and management strategies, policymakers can mitigate the impact of diabesity on individuals, communities, and healthcare systems.

Malta is a small island country in Europe, situated in the middle of the Mediterranean Sea and is known to have a high prevalence of diabetes and obesity among its population (Cuschieri et al. 2016; Cuschieri 2020). Malta provides the perfect landscape to explore these two conditions at a population level, where such evidence will have both local and international significance for public health and policymakers. This is timely as it provides the baseline for the pre-COVID population landscape that would enable post-pandemic strategies to be built upon. Our study is set to explore: (i) the characteristics of both diabetes and diabesity at a population level, (ii) potential co-determinants linked to both conditions, (iii) the relationship between different adiposity indices in both diabetes and diabesity, and (iv) whether diabetes and/or diabesity increases the risk of all-cause mortality across a period of 7 years.

Methods

Data

A nationwide health examination survey, using the European Health Examination Survey (EHES) guidelines, was conducted between 2014 and 2016 (Tolonen 2016a, b, c). The sampling was carried out through a randomized single stage stratification (by age, gender, and locality) using the national passport register. The target population was adults between the ages of 18 and 70 years, of both sexes, that had lived in Malta for at least 6 months and were not pregnant. Examination was carried out in each town using the state's peripheral clinics. Participants who accepted our invitation letter completed an interviewer-led socio-demographic and medical history questionnaire followed by measurements of blood pressure, body weight (in Kg), waist circumference (in cm), hip circumference (in cm), and height (in meters). Blood samples for fasting blood glucose (FBG) and lipid profile were also taken. To maintain national representation, a weighting factor was applied to the participating population ($n = 1861$). The detailed protocol can be found elsewhere (Cuschieri et al. 2016). The Research Ethics Committee of the Faculty of Medicine and Surgery at the University of Malta (FRECMDS_2014_7) together with the Information and Data protection commissioner gave their permission for this study. All participants gave their informed written consent to participate in the study.

In 2021, following ethical approval (FRECMDS_1819_133) and permissions, the study population was cross-linked with the national mortality register and the ICD-10 codes for those that died were provided by the Directorate for Health Information and Research.

Definitions

The socio-demographic characteristics gathered were highest education level, employment status, residing districts, smoking habits, alcohol consumption, and physical activity.

The education level definition followed the ISCED-1997 criteria and was categorized as: no formal education, primary education level, unfinished secondary level, finished secondary level, tertiary level, university level, and postgraduate level (United Nations Educational, Scientific and Cultural Organisation 1997). For this study's analyses, the educational levels were combined into three categories: (i) "low education" where participants did not finish the recommended/mandatory educational level (combination of formal education, primary education level, unfinished secondary level); (ii) "medium education" where participants completed the recommended/mandatory educational level (finished secondary level); (iii) "high education" where participants continued their education to higher levels (combination of tertiary level, university level, and postgraduate level).

Employment status was categorized as (i) employed; (ii) unemployed; (iii) student; (iv) retired; (v) domestic tasks. Residing districts followed the Eurostat system of Local Administrative Units (LAUs) where the different localities across the islands were grouped into six districts (Northern Harbour, Southern Harbour, Southeast, Western, Northern, and Gozo) (National Statistics Office of Malta 2023).

Smoking habit was defined as having smoked at least one cigarette packet in a week over a period of 12 months. Alcohol consumption was defined as the consumption of at least one unit of an alcoholic beverage per week over a period of 12 months. Physical activity for a typical week was recorded by following a literature-based validated tool which followed the categories: (i) no activity, (ii) at least 10 min of walking, (iii) moderate activity, and (iv) vigorous activity (Meriwether et al. 2006).

Waist circumference was measured as midway between the lower rib margin and the iliac crest. Hip circumference was measured at tip of the iliac crest. Body mass index (BMI) was calculated by dividing the body weight (in kg) by the height squared (in meters). The definition for BMI followed the WHO criteria, where a BMI of < 24.99 kg/m^2, but > 18.4 kg/m^2, was labeled as normal; 25–29.99 kg/m^2 as overweight and ≥ 30 kg/m^2 as obese (World Health Organization 2024a). The waist–hip ratio was calculated by dividing the waist circumference (in cm) by the hip circumference (in cm), while the waist–height ratio was calculated by dividing the waist circumference (in cm) by the height (in cm) (World Health Organization 2024b). A waist circumference of < 88 cm in women and < 102 cm in men was considered as normal (Klein et al. 2007). A waist–hip ratio < 0.85 in women and < 0.80 in men was considered as normal, while a weight–height ratio ≤ 50 for both sexes was considered as normal (Ashwell and Gibson 2009).

The A Body Shape Index (ABSI) estimates the abdominal adiposity as well as predicts the risk of premature mortality from cardiovascular disease, cancer, and diabetes (Krkauer and Krakauer 2012). This index considers age, sex, body weight, height, and waist circumference and provides the $ABSI_z$ score, which categorizes mortality risk into very low, low, average, high, and very high. The $ABSI_z$ score was calculated using an online tool (Omni Calculator n.d.).

The Body Adiposity Index (BAI) estimates the percentage of body adiposity using height and hip circumference (Bergman et al. 2012). It has been shown to provide a similar accuracy to BMI (Freedman et al. 2013). The BAI was calculated using an online tool (Omni Calculator n.d.). The BAI classification followed the literature and categorized participants, according to sex and age, into four categories: underweight, healthy, overweight, and obese (Gallagher et al. 2000).

Participants with a history of type 2 diabetes mellitus (T2DM), on oral hypoglycaemic agents, or scoring an FBG above 7 mmol/L were labeled as T2DM. Participants having a diagnosis of both T2DM and obesity were labeled as having diabesity (American Diabetes Association Professional Practice Committee 2024).

Data analyses

The study population was categorized into different health statuses (i) diabetes, (ii) obesity, and (iii) diabesity. The sociodemographic characteristics were categorically compared according to the different health statuses (diabetes vs. non-diabetes; obesity vs. non-obesity; diabesity vs. non-diabesity) using the chi-square test. The sociodemographic characteristics showing significance were considered to be confounding variables for the regression analyses.

The diabetes and the diabesity cohorts were further evaluated against the different adiposity indices (BMI, BAI classification, waist circumference, waist–hip ratio, waist–height ratio, and ABSI risk). Comparisons between the different cohorts (diabetes vs. non-diabetes; and diabesity vs. non-diabesity) and the various adiposity indices were carried out using the chi-square test.

Multivariate binary logistic regression analysis was carried out with a diagnosis of diabetes (vs. not) as the dependent variable and the different adiposity indices as the independent variables while adjusting for sex, age, locality, education level, employment status, and alcohol consumption. Only significant relationships were reported.

Mortality data analyses

The cohort that died over 7 years (2014 to 2021) was stratified by cause of death through the defined ICD-10 codes and grouped into the following categories: cancer, brain haemorrhage, cardiac pathology, diabetes mellitus, obesity, road traffic accident, brain pathology not cancer (CA), lung pathology not cancer (CA), and gastrointestinal tract (GIT) pathology. The frequency of each mortality cause was calculated.

Cox proportional hazard models were performed to estimate the hazard of all-cause mortality for diabetes and diabesity. The models for the time of death were fitted to adjust for age, gender, employment status, education level, and alcohol status along with a different adiposity index for each model (model 1 – BMI; model 2 – ABSI; model 3 – BAI; model 4 – waist circumference).

A p value less than or equal to 0.05 was considered as significant.

Results

The adjusted study population was of 3947 adults (men $n = 1998$), with a response of 47.15%. The obesity prevalence was 34.08% (CI 95% 32.62–35.57; $n = 1345$), while the type 2 diabetes prevalence was 10.31% (CI 95% 9.40–11.30; $n = 407$). Out of which, 56.02% (CI 95% 51.16–60.76, $n = 228$) had a concurrent obesity status. Therefore, the diabesity prevalence was 5.78% (CI 95% 5.09–6.55; $n = 228$) of the total adjusted study population.

Similar socio-behavioral characteristics were present across the diabetes, obesity, and diabesity cohorts, as shown in Table 1. The three cohorts were observed to

Table 1 Socio-behavioral characteristics of the participants having diabetes, obesity, and diabesity

		Diabetes cohort ($n = 407$)	p value[1]	Obesity cohort ($n = 1345$)	p value[2]	Diabesity cohort ($n = 228$)	p value[3]
Sex	Female	33.42%	< 0.001	45.28%	< 0.001	37.28%	< 0.001
	Male	66.58%		54.72%		62.72%	
Age groups	18–19	0.00%	< 0.001	1.26%	< 0.001	0.00%	< 0.001
	20–29	0.00%		0.45%		0.00%	
	30–39	1.23%		13.98%		0.00%	
	40–49	3.44%		14.42%		3.07%	
	50–59	14.74%		18.88%		11.84%	
	60–69	27.76%		27.51%		34.65%	
	70	52.83%		23.64%		50.44%	
Locality	Southern Harbour	20.88%	0.12	18.66%	< 0.001	22.81%	0.02
	Northern Harbour	30.47%		25.80%		26.32%	
	South Eastern	11.55%		17.40%		15.35%	
	Western	15.48%		16.21%		19.30%	
	Northern	12.53%		12.19%		8.33%	
	Gozo	8.85%		9.74%		7.89%	
Education level	Low education	38.33%	< 0.001	23.72%	< 0.001	44.74%	< 0.001
	Medium education	37.59%		43.79%		35.96%	
	High education	24.08%		32.49%		19.30%	
Employment status	Employed	41.52%	< 0.001	58.29%	< 0.001	39.47%	< 0.001
	Unemployed	1.72%		1.86%		1.32%	
	Student	0.49%		1.93%		0.88%	
	Retired	37.10%		15.54%		35.09%	
	Domestic tasks	19.16%		22.53%		23.25%	
Smoking habit status	Smoking	24.08%	0.91	21.41%	0.002	19.30%	0.07
	Non-smoking	75.92%		78.59%		80.70%	
Alcohol habit status	Yes	48.40%	0.03	46.99%	< 0.001	45.18%	0.01
	No	51.60%		53.09%		54.82%	
Physical activity status	No activity	8.35%	0.06	9.07%	0.03	10.09%	0.52
	Walk	14.74%		21.56%		15.35%	
	Moderate activity	64.86%		58.14%		62.28%	
	Vigorous activity	12.04%		11.23%		12.28%	

p value[1]: chi sq. diabetes vs. non-diabetes

p value[2]: chi sq. obesity vs. non-obesity

p value[3]: chi sq. diabesity vs. non-diabesity

consist of mostly men, residing in the Northern Harbour region, employed, and following a favorable behavioral lifestyle habit (non-smokers, no regular alcohol, moderately physically active).

A large proportion of the study population fell within the "obese" status; hence, it was considered appropriate to investigate the body weight and presence of adiposity using different indices across the diabetes and diabesity cohorts. Most of the diabetes cohort was categorized as being obese through the body adiposity index (BAI), as well as exhibited a high waist circumference and waist–hip ratio. However, this cohort exhibited a predominantly low ABSI risk, as shown in Table 2. A homogenous picture was observed for the diabesity cohort, as shown in Table 3.

Multivariate regression analysis indicated an increase in age (OR 1.09 CI95% 1.08–1.11; $p \leq 0.001$) and increase in waist circumference (OR 1.04 CI95% 1.02–1.05; $p \leq 0.001$) were associated with developing diabetes, while being female (OR 0.49 CI95% 0.33–0.74; $p = 0.001$) had the opposite relationship.

The presence of diabesity was associated with an increase in age (OR 1.10, 95% CI 1.07–1.12; $p \leq 0.001$), increase in waist circumference (OR 1.09 CI95% 1.07–1.12; $p \leq 0.001$), having a low educational level

Table 2 Comparisons between adiposity indices and the diabetes vs. non-diabetes cohorts

		Total population		
		DM ($n = 407$)	Non-DM ($n = 3540$)	p value
BMI (kg/m^2)	≤24.99	7.37%	32.85%	< 0.001
	25.00–29.99	36.61%	35.59%	
	30.00 +	56.02%	31.55%	
BAI classification	Underweight	2.21%	6.61%	< 0.001
	Healthy	16.95%	39.44%	
	Overweight	32.92%	30.00%	
	Obese	47.91%	22.57%	
Waist circumference (cm)	Normal (< 88 F, < 102 M)	4.42%	28.45%	< 0.001
	High (≥ 88 F, ≥ 102 M)	95.58%	71.55%	
Waist–hip ratio	Normal (< 0.85 F, < 0.80 M)	0.49%	6.86%	< 0.001
	High (≥ 0.85 F, ≥ 0.80 M)	99.51%	93.14%	
Waist–height ratio	Normal (≤ 0.50)	0.00%	0.06%	0.715
	High (0.51 +)	100.00%	99.94%	
ABSI risk	Very low	35.87%	53.05%	< 0.001
	Low	23.34%	21.50%	
	Average	22.36%	11.10%	
	High	9.58%	7.85%	
	Very high	8.85%	6.50%	

M Male, *F* Female

Table 3 Comparisons between adiposity indices and the diabesity vs. non-diabesity cohorts

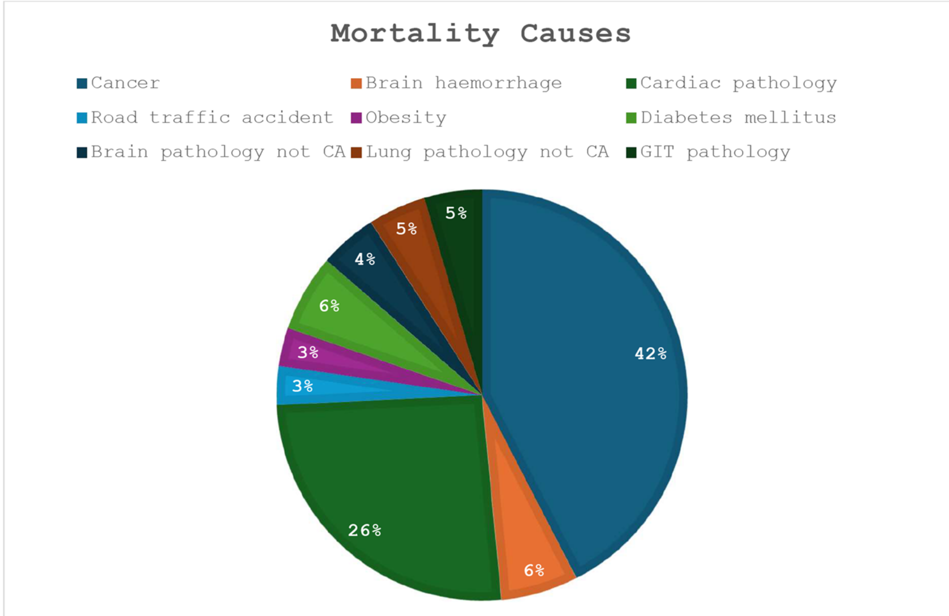
		Total population		
		Diabesity ($n = 228$)	Non-diabesity ($n = 3719$)	p value
BAI classification	Underweight	0.00%	6.53%	< 0.001
	Healthy	7.89%	38.94%	
	Overweight	17.11%	31.14%	
	Obese	75.44%	22.10%	
Waist circumference (cm)	Normal(< 88 F, < 102 M)	0.44%	27.53%	< 0.001
	High (≥ 88 F, ≥ 102 M)	99.56%	72.47%	
Waist–hip ratio	Normal (< 0.85 F, < 0.80 M)	0.88%	6.53%	< 0.001
	High (≥ 0.85 F, ≥ 0.80 M)	99.12%	93.47%	
Waist–height ratio	Normal (≤ 0.50)	0.00%	0.05%	0.726
	High (0.51 +)	100.00%	99.95%	
ABSI risk	Very low	39.04%	52.03%	< 0.001
	Low	20.18%	21.78%	
	Average	23.68%	11.56%	
	High	9.65%	7.93%	
	Very high	7.46%	6.70%	

M male, *F* female

(OR 2.19 CI95% 1.39–3.45; $p = 0.001$), and education till secondary school (OR 1.63 CI95% 1.06–2.51; $p = 0.03$), while being female (OR 0.53 Ci95% 0.30–0.93; $p = 0.03$) and decrease in ABSI score (OR 0.79 CI95% 0.71–0.87; $p \leq 0.001$) had the opposite relationship on multivariate regression analysis.

Mortality across 7 years

Over a period of 7 years, 1.67% of the study population ($n = 3947$) died, with the commonest cause of mortality reported as cancer, as shown in Fig. 1. The direct cause of mortality due to diabetes was 6.06% and obesity 3.03%.



CA = cancer
GIT = Gastrointestinal

Fig. 1 Reported mortality causes for the study population that died between the years 2014–2021. *CA*, cancer; *GIT* Gastrointestinal

On cross-linking those that died with their baseline characteristics (2014–2016), 25.76% (CI95% 16.75–37.44) were labeled as having diabetes, 40.91% (CI95% 29.87–52.95) as having an overweight status, and 30.30% (CI95% 20.55–42.22) as obese.

Diabetes exhibited a significant mortality risk through cox proportional hazard model (HR 2.65 CI95% 1.20–5.85; $p = 0.02$) while diabesity had borderline significance ($p = 0.06$). On adjustment for potential confounding factors, diabetes mortality risk remained significant, as shown in Table 4.

Discussion

Diabesity and associated mortality in Malta

The SAĦĦTEK national health examination survey (HES) identified that Malta has a high prevalence of obesity, greater than the estimated global and European prevalences (GBD 2015 Obesity Collaborators et al. 2017). Similarly, the prevalence of T2DM was also above the European average (OECD 2016), with more than half of the population with diabetes also having an obese status. This alarming overlap emphasized the complex interplay between insulin resistance and adiposity, resulting in critical public health concern

Table 4 Adjusted HRs for diabetes mortality based on different adiposity indices

	HR (95% CI)			
	Multivariable model 1	Multivariable model 2	Multivariable model 3	Multivariable model 4
Diabetes	2.88 (1.20–6.91)*	3.38 (1.19–9.58)*	3.15 (1.31–7.62)*	2.63 (1.08–6.37)*
Age	1.01 (0.96–1.06)	1.02 (0.96–1.09)	0.99 (0.95–1.04)	0.99 (0.94–1.05)
Gender	1.96 (0.88–4.34)	1.62 (0.75–3.49)	3.17 (1.20–8.37)*	1.55 (0.72–3.33)
Labor status	0.88 (0.68–1.13)	0.85 (0.66–1.08)	0.86 (0.67–1.11)	0.83 (0.65–1.06)
Educational level	0.81 (0.36–1.83)	0.81 (0.35–1.88)	0.69 (0.30–1.55)	1.63 (0.77–3.46)
Alcohol status	1.77 (0.84–3.76)	1.47 (0.66–3.26)	1.62 (0.76–3.43)	1.63 (0.77–1.05)
BMI	1.06 (0.99–1.14)			
ABSI		0.06 (0.88–2.98)		
BAI			1.08 (1.01–1.16)*	
Waist circumference				1.02 (0.99–1.05)

$^{*}p \leq 0.05$

while demonstrating heightened insulin resistance within the Maltese population (Kahn and Flier 2000). Such a scenario not only underscores possible deficiencies in both preventive measures and patient management strategies but also carries significant implications for both individuals and the nation. At the individual level, the coexistence of diabetes and obesity significantly diminishes the quality of life, while on a national scale, it amplifies the strain on the national healthcare system and economic workforce sectors (Shah et al. 2023; Tremmel et al. 2017).

A considerable percentage of decedents were certified as having diabetes and obesity, with rates comparable to the literature (Duncan et al. 2010; Mcewen et al. 2018), although T2DM and obesity as causes of death, mentions on death certification are likely under-reported (Buckley et al. 2014). Even though obesity and T2DM were listed as primary causes of death in the minority of decedents, their pathophysiological effects significantly contribute to overall mortality risk (Li et al. 2019; Abdelaal et al. 2017). This is supported by this study's findings where having T2DM resulted in more than a twofold increased risk of mortality.

Diabesity demographic and socio-economic disparities

Regression analysis identified that older men with low levels of education are at increased risk of having diabesity. The notable age and gender disparities underscore variances in physiological and behavioral attributes across genders and along the spectrum of life stages (Kalra et al. 2021; Jura and Kozak 2016). Diabesity was similarly noted to be increasing with age in Turkey and Spain, with López-González et al. (2022) also noting diabesity to be more prevalent among men (López-González et al. 2022; Yumuk et al. 2005).

Ageing brings about a multitude of physiological changes that can heighten the risk of T2DM and obesity. These changes include decreased insulin sensitivity due to shifts in body composition, such as increased adiposity and reduced muscle mass, as well as impaired pancreatic function leading to decreased insulin secretion (Wilcox 2005). Behavioral factors also play a significant role, with sedentary lifestyles and poor dietary habits exacerbating insulin resistance and weight gain, particularly in older adults (Batsis and Villareal 2019). Furthermore, hormonal shifts associated with ageing, such as decline in testosterone levels in men and oestrogen in women, contribute to changes in body composition and insulin sensitivity, further increasing the risk of T2DM and obesity (Pataky et al. 2022; Horstman et al. 2012; Jayedi et al. 2020). Gender differences in body composition, hormone levels, and behaviour may explain variations in the prevalence of these conditions between men and women (Geer and Shen 2009; Suchacki et al. 2022; Karastergiou et al. 2012).

Geographic inequalities were also noted, with the prevalence of obesity being greatest in Malta's Northern Harbor region, the nation's most densely populated region (National Statistics Office GoM 2023). Such highly developed and densely urban landscapes have been strongly associated with developing T2DM and obesity, not only in Malta but across the globe (Anza-Ramirez et al. 2022; Fenech and Aquilina 2020). This relationship also increased dependence on personal transportation in these areas which brings about increased traffic and air pollution, and lack of greenspaces, which all contribute to increased T2DM and obesity prevalence (Sørensen et al. 2022; Shi et al. 2022).

Increased levels of education were noted to serve as protective factors against diabesty. Although the precise association between educational attainment and the dual diabetes–obesity epidemic has not been extensively investigated, it is postulated that similar behavioral mechanisms underlie both the correlation between higher education levels and reduced risk of developing diabetes and obesity individually. Specifically, individuals with advanced education levels tend to exhibit heightened awareness of preventive measures and disease self-management techniques (Mazariegos et al. 2021; Adams and Boutwell 2020).

Adiposity and diabesity

A significant proportion of the study cohort was classified as "obese" through BMI, prompting a thorough investigation into body weight and adiposity using various indices within the cohorts affected by diabetes and diabesity. The population classified as "obese" also had a high BAI, waist circumference and waist–hip ratio, evidencing the presence of significant adiposity among the Maltese population, demonstrating the urgency and heightened priority of tackling obesity.

Interestingly, despite the high prevalence of obesity and adiposity, the diabetes cohort exhibited a predominately low risk according to the A Body Shape Index (ABSI) on regression analysis. This suggests that accuracy of the ABSI may be confounded by the presence of diabetes. Diabetes can affect body composition and fat distribution, which might impact the accuracy of waist circumference measurements used in ABSI calculation (Gomez-Peralta et al. 2018; Solanki et al. 2015; Lin et al. 2021). Thus, it is essential to consider how diabetes and its complications might affect the interpretation of the score. It also calls for further research in this area.

Moreover, diabetes is associated with an increased risk of cardiovascular disease, independent of obesity (Leon and Maddox 2015), and the ABSI score is designed to reflect cardiovascular risk (Ofstad et al. 2019). Therefore, in individuals with both obesity and diabetes, the ABSI score may still provide valuable information about their overall health risk, but it should be interpreted cautiously, taking into account the presence of diabetes and other relevant factors, highlighting the need to use multiple indices to assess obesity comprehensively.

Our study demonstrated that T2DM is a significant factor for mortality, while the only adiposity index that was significantly correlated with mortality risk was the BAI index. This finding suggests that BAI may capture unique aspects of body fat distribution or metabolic health that are particularly pertinent to mortality risk. Potential explanations for BAI's association with mortality risk include its ability to delineate visceral fat deposition, which is recognized as a key determinant of adverse health outcomes (Longo et al. 2019; Frank et al. 2018), as well as its potential to better reflect metabolic dysfunction compared to conventional indices such as BMI. Additionally, the limitations inherent in other indices employed in the study may have influenced their lack of association with mortality risk, such as the inability of BMI to discriminate between lean mass and fat mass or to adequately capture variations in body fat distribution. However, the BAI's gender disparities and opposing evidence must be acknowledged (Rost et al. 2018; Moliner-Urdiales et al. 2014). Nonetheless, this study highlights the complex interplay between adiposity, diabetes mellitus, and mortality risk, highlighting the need for further investigation into the underlying mechanisms and validation of findings across diverse populations.

COVID-19 pandemic's impact on T2DM and obesity

When studying the COVID-19 pandemic and its mitigation measures, it becomes evident that individuals with T2DM and obesity encountered increasing challenges, not only in Malta but across the globe (Nour and Altintaş 2023; Corrao et al. 2021). The pandemic has led to disruptions in routine healthcare services, hindering access to regular check-ups, medications, and lifestyle interventions crucial for managing these conditions. Moreover, lockdown measures and social distancing restrictions have contributed to increased sedentary behaviour, reduced physical activity levels, and altered dietary habits, all of which are risk factors for both T2DM and obesity (Kendzerska et al. 2021). Furthermore, pandemic-induced stress, anxiety, and depression have also played a role in exacerbating these conditions, as emotional distress can lead to unhealthy coping mechanisms such as overeating and poor self-care (Melamed et al. 2021). The intertwined effects of the pandemic and mitigation efforts along with the pre-pandemic T2DM and obesity landscape, as shown in this study, underscore the critical need for targeted interventions and support systems to mitigate the impact on individuals with T2DM and obesity, ensuring access to essential healthcare services, promoting healthy lifestyles, and addressing mental health concerns.

Implications to policy and practice in the post-COVID era

Despite utilizing data collected before the COVID-19 pandemic, the implications of this study for policy and practice remain valid, offering insights that can inform strategies to address the intertwined challenges of diabesity and associated mortality. Across various sectors, from healthcare to urban planning, there is a pressing need for multifaceted approaches that target risk factors and promote healthy behaviors (Bai et al. 2012). Policy initiatives must prioritize preventive measures, such as promoting healthy eating habits and encouraging physical activity, while also addressing demographic and socio-economic disparities identified in the study, particularly among older men with lower levels of education, who are at heightened risk. Integrated healthcare delivery models should be adopted to ensure comprehensive care and support for individuals with these conditions, emphasizing early detection and screening using a range of measures beyond traditional BMI. Moreover, efforts to improve health literacy and empower individuals to make informed lifestyle choices are crucial, as is the creation of built environments conducive to physical activity and sustainable transportation options. Training for healthcare professionals and capacity building for community health workers are also essential components of effective intervention strategies. Finally, ongoing evaluation and monitoring of policy interventions are necessary to assess their impact and guide future efforts.

Additionally, there is a pressing need to address the root causes of diabetes and obesity, such as unhealthy dietary habits and sedentary lifestyles, through comprehensive health promotion campaigns and community-based initiatives. Furthermore, the integration of digital health technologies and telemedicine into healthcare delivery systems has become increasingly important in the post-COVID era (Bouabida et al. 2022; Getachew et al. 2023). Investing in the development and implementation of telehealth infrastructure is recommended, as such technologies improve access and engagement with healthcare services while enabling remote monitoring of chronic conditions.

Strengths and limitations

The strengths of this study lie in its nationwide representation achieved through adherence to EHES guidelines, ensuring comprehensive coverage of Malta's adult population. By employing a multidimensional analytical framework, the study delved into various socio-demographic characteristics, adiposity indices, and mortality data, offering a nuanced understanding of the intricate relationship between diabetes, obesity, and mortality. Further, the longitudinal analysis spanning 7 years, facilitated by integration with the national mortality register, provided invaluable insights into the temporal dynamics of these health outcomes. Statistical adjustment through multivariable binary logistic regression bolstered the validity of findings, illuminating independent predictors of diabetes, obesity, and diabesity, although other confounding factors that were not accounted for could have had an effect on these relationships. Moreover, this study's findings have clinical relevance as they unveil demographic and socio-economic disparities associated with these conditions, thereby informing targeted interventions and clinical practice guidelines.

The response rate achieved in this study is satisfactory given the nature of the study and broader trends in research participation. The study involved invasive procedures such as health examinations and blood sample collection, which may have deterred some individuals from participating (Noirmain et al. 2020). Additionally, the declining trend in research participation rates over recent years further underscores the challenge of securing high response rates in epidemiological studies (Arfken and Balon 2011).

Conversely, limitations inherent in the study warrant acknowledgment. Its cross-sectional design impedes the establishment of causal relationships between diabetes and obesity, cautioning against definitive interpretations of observed associations. Reliance on self-reported measures for variables such as smoking habits and physical activity introduces potential biases.

Conclusion

This study provides a comprehensive examination of the complex interplay between diabetes, obesity, and mortality in Malta. By adhering to EHES guidelines and employing a multidimensional analytical approach the study's findings underscore the urgent need for targeted interventions and policy initiatives to address modifiable risk factors and reduce the burden of diabetes and obesity on public health. Moving forward, concerted efforts are required to enhance population health literacy, promote healthy behaviors, and create supportive environments conducive to healthy living. By translating research findings into actionable policies and evidence-based practices, stakeholders can collaboratively work toward mitigating the impact of diabetes, obesity, and associated mortality, ultimately fostering the health and well-being of individuals in Malta and beyond.

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Data availability Data is not availble as per ethical approval agreement.

Declarations

Ethical approval The Research Ethics Committee of the Faculty of Medicine and Surgery at the University of Malta (FRECMDS_2014_7) together with the Information and Data protection commissioner gave their permission for this study. All participants gave their informed written consent to participate in the study. In 2021, following ethical approval (FRECMDS_1819_133) and permissions, the study population was cross-linked with the national mortality register and the ICD-10 codes for those that died were provided by the Directorate for Health Information and Research.

Consent to participate Research involved human participants. Informed consent was obtained from all individual participants included in the study.

Competing interests All authors have no competing interests to disclose.

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