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Changes in body weight and cardiovascular risk factors in a Chinese population with type 2 diabetes mellitus: a longitudinal study

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Introduction: The primary care management of blood glucose, blood pressure, lipid profiles, and body weight is important among patients with type 2 diabetes mellitus (T2DM) to prevent disease progression. Information on how weight changes would improve or deteriorate cardiovascular (CV) risk factors is warranted for making primary care recommendations. We aimed to investigate the changes in body weight and CV risk factors and to analyse their association in a Chinese population with T2DM.

Methods: We retrieved longitudinal data between 2020 and 2021 from 1,758 adult primary care patients enrolled in a diabetic retinopathy (DR) screening programme. Linear associations of changes in body weight with CV risk factors were explored. Multivariable logistic regression analysis was performed to examine associations between different weight change categories and the worsening of CV risk factors.

Results: The mean age of all the participants was 63.71 years, and over half of participants were females. During a one-year follow-up period, 24.7% of patients had a weight loss of $\geq 3\%$, while 22.2% of patients had a weight gain of $\geq 3\%$. Patients who had a weight loss of $\geq 3\%$ were more likely to prevent the worsening of haemoglobin A1c (HbA1c) and triglycerides, while those who had a weight gain of $\geq 3\%$ tended to have worsened HbA1c, lipid profiles, and blood pressure.

Conclusion: Results from this real-world investigation suggested the concurrent need for weight loss intervention among patients who are overweight or obese and weight gain prevention among patients whose body weight falls within the normal range in the context of community-based diabetes management.

KEYWORDS

weight changes, cardiovascular risk factors, type 2 diabetes mellitus, primary care, general practice, community medicine

1 Introduction

The global prevalence of diabetes was estimated at 9.3% in 2019, and it is predicted that this number will rise to 10.2% (578 million people) by 2030, and 10.9% (700 million people) by 2045 (1). Adults with type 2 diabetes mellitus (T2DM) are at high risk of cardiovascular (CV) disease, which represents the most common complication and the leading cause of mortality in people with T2DM (2, 3). This has contributed substantially to treatment costs for T2DM at both individual and population levels globally (4). Elevated blood pressure (BP), blood glucose, and lipid levels are all important physiological and biochemical risk factors closely associated with the onset of CV disease (5). Obesity is a pathological condition that plays a central role in the pathophysiology of T2DM while aggregating several CV risk factors (6–8). Weight gain has been shown to be associated with the worsening of CV risk factors and increased risk of metabolic syndrome (9, 10), yet obesity management is still challenging particularly in low- and middle-income countries (11).

Current estimates suggest that nearly 130 million people are living with diabetes in China (12), which account for nearly one-fourth of patients with diabetes worldwide. Compared to western countries where the majority of patients with diagnosed diabetes are overweight or obese (5, 13), a large proportion (43%) of patients with T2DM in China are of normal weight with a body mass index (BMI) falling within the range of 18.5 kg/m² to 23.9 kg/m² (14). However, previous studies on the relationship between changes in weight and a set of CV risk factors including BP, blood glucose and lipid levels were mainly conducted in the overweight or obese population, with less attention paid to people with normal weight (15–18). Further investigations are warranted to understand how weight changes may impact CV risk factors in the Chinese population with T2DM.

Much evidence from randomised controlled trials indicates that lifestyle interventions on weight management could significantly improve CV risk factors in T2DM patients (16, 19, 20). However, trials conducted in clinical settings are often difficult to reflect the exposure-outcome relationships in real-world settings (21). The significant effect achieved in clinical trials may not necessarily translate into sustainable lifestyle modification in daily practice and community settings (22, 23). Given the widespread difficulties in weight loss in diabetes management, information on how weight changes would improve or deteriorate CV risk factors is essential for making tailored primary care recommendations to successfully prevent the progression of T2DM (24).

The main objective of this study was to assess the longitudinal changes in body weight and CV risk factors in a primary care population with T2DM. The study also aimed to address the research question of whether there is a significant association between different weight change categories and changes in haemoglobin A1c (HbA1c), BP, and lipid profiles in the study population.

2 Materials and methods

2.1 Study design

This was a longitudinal, observational study conducted in Guangdong province, southern China between September 2020 and December 2021. The study was part of a larger project on screening for diabetic retinopathy (DR) in collaboration with the Guangzhou Diabetic Eye Study Group at the Zhongshan Ophthalmic Center, Sun Yat-Sen University. The anthropometric and clinical parameters including weight, height, BP, HbA1c, and lipid profiles were measured annually from September 2020 to January 2021, and from September 2021 to December 2021, respectively. The study period did not cover the Chinese New Year to minimise the possibility of acute diet change.

2.2 Setting and data source

The study participants were patients with diabetes who were drawn from community and township health centres. These community-based primary care facilities offer a comprehensive package of diabetes management care that is integrated as part of the free-of-charge, national basic public health service delivery (25, 26). Routine diabetic care includes periodic blood glucose tests, regular follow-up exams, and tailored advice on medicine use, diet modification, and physical exercise. An interviewer-administered questionnaire was used to collect information on socio-demographics (i.e., age, sex, education level, place of residence, marital status, living relationships, and household income), lifestyle behaviours, medical history, and drug use. The anthropometrics (i.e., height and weight) and BP parameters were measured by clinical staff. The HbA1c and lipid panel testing was performed in centralised clinical laboratory. The check-up data were retrieved electronically from the computerised records.

2.3 Participants

The target subjects in the study were primary care patients with clinically-diagnosed T2DM. Diabetes was diagnosed as a fasting plasma glucose level ≥ 7.0 mmol/L or HbA1c $\geq 6.5\%$ (27). The presence of T2DM was assessed by the attending primary care physician according to the Chinese Diabetes Society guideline and the World Health Organization (WHO) recommendation (27, 28). A total of 1,795 patients with T2DM participated in both the 2020 and 2021 waves of DR screening. We excluded patients who did not have body weight measured in either wave ($n=22$). Patients with weight change below $P_{0.5}$ or above $P_{99.5}$ ($n=15$) were also excluded to take into account the possible measurement error while minimising the impact of excess weight loss or weight gain on the change of CV risk factors. This yielded a total of 1,758 patients with T2DM included in the final analysis.

2.4 Study variables and measurements

Self-reported information on age, sex, residence place, education level, living relationships, marital status, household income, smoking status, drinking status, duration of diabetes, medical history (e.g., hypertension, heart disease, and stroke), and current use of antihypertensive drugs and glucose-lowering agents was collected. The anthropometric parameters were measured by medical staff following a standardised protocol. Weight was measured with light clothing and without shoes by a calibrated weighing scale. Height was measured using a wall-mounted stadiometer with the position of the body being straight against the wall. The BMI was calculated as weight in kilograms divided by squared height in meters (kg/m^2). BP was measured by routinely validated automatic sphygmomanometers at a seated position after at least 5 minutes of rest, and the arm with the higher BP values was used. The average of two BP readings, 1-2 min apart, was recorded. A fasting venous blood sample was collected. Plasma cholesterol, triglycerides, and HbA1c were measured using an automated, clinical chemistry analyzer (TBA-120FR, Toshiba, Japan) with coefficients of variation in compliance with the laboratory measurement standard.

2.5 Definitions

Weight gain was defined as an increase of 3% and above in body weight during 2020-2021, while weight loss was defined as a decrease of 3% and more in body weight during the same study period. A change in body weight of at least 3% has been considered clinically meaningful given that it is unlikely caused by measurement error or normal weight fluctuations (29–31). Worsening of HbA1c, triglycerides, total cholesterol, low-density lipoprotein (LDL) cholesterol, systolic BP, and diastolic BP were defined as increased values in 2021 compared with that in 2020, except for high-density lipoprotein (HDL) cholesterol which was defined as decrease values in 2021 compared with that in 2020.

2.6 Statistical analysis

Data entry was performed by two trained research assistants with double verification using EpiData 3.1 (Denmark). Descriptive statistics were used to describe the demographics, lifestyle behaviours, medical history, and clinical parameters of patients according to different weight change categories. Between-group differences were assessed by independent *t*-tests or chi-square tests, where appropriate. Pearson correlation between weight change and CV risk factor change was determined. The proportion of patients with worsening CV risk factors were plotted against different weight change categories, and tests for trend were conducted. Multivariable logistic regression analysis was performed to explore the association with a 95% confidence interval (95%CI) between different weight change categories and worsening of CV risk factors after adjusting for age, sex, baseline BMI,

education level, residence place, marital status, living relationships, household income, smoking status, alcohol drinking, duration of diabetes, antihypertensive medication use, oral hypoglycaemic drugs use, insulin use, and presence of CV comorbidities. Data analysis was conducted using Stata 14 (StataCorp, TX). A *p*-value <0.05 was considered statistically significant.

2.7 Ethics consideration

All participants provided written informed consent. Data anonymisation was performed by removing all patient identifiers from the dataset prior to data analysis. Ethics approval was granted by the Zhongshan Ophthalmic Center Medical Ethics Committee (Ref: 2017KYPJ094) at Sun Yat-Sen University following the Declaration of Helsinki 2013.

3 Results

3.1 Characteristics of study participants

A total of 1,758 patients with T2DM who met the eligibility criteria were included in the study. The mean age and baseline BMI of all participants was 63.71 years (standard deviation [SD]: 9.39) and 24.36 kg/m^2 (SD: 3.36), respectively. More than half of the participants (56.3%) were females. Almost one-fourth (24.7%) of patients had a weight loss of $\geq 3\%$, and their mean baseline BMI was 24.63 kg/m^2 . Slightly above one-fifth (22.2%) of patients had a weight gain of $\geq 3\%$, and their mean baseline BMI was 23.39 kg/m^2 . The weight gain group had the highest proportion of patients with formal education and those who were rural residents (Table 1). A higher proportion of patients who had concurrent hypertension and antihypertensive drug use was observed in the weight loss group (Table 2). There were no significant differences in the distribution of age, sex, marital status, living relationships, smoking status, alcohol drinking, household income, duration of diabetes, presence of CV comorbidities, and glucose-lowering medication use across the three groups.

3.2 Changes in body weight and CV risk factors

Haemoglobin A1c, HDL cholesterol, and triglycerides decreased significantly between 2020 and 2021, while LDL cholesterol increased during the study period. We did not observe significant changes in body weight, total cholesterol, systolic BP, and diastolic BP over time. In addition, we observed significant correlations of weight change with a set of changes in HbA1c (Pearson correlation [*r*]=0.096, *p*<0.001), LDL cholesterol (*r*=0.070, *p*=0.007), triglycerides (*r*=0.133, *p*<0.001), total cholesterol (*r*=0.070, *p*=0.007), systolic BP (*r*=0.136, *p*<0.001), and diastolic BP (*r*=0.083, *p*<0.001). There was also no

TABLE 1 Baseline characteristics of study participants by different weight change categories.

Variables	All patients (N =1,758)	Weight loss (n=434)	Weight stability (n=933)	Weight gain (n=391)	p-value
Age, years	63.71 (9.39)	63.69 (9.52)	64.05 (9.32)	62.90 (9.40)	0.123
Sex					
Male	768 (43.7%)	183 (42.2%)	415 (44.5%)	170 (43.5%)	0.721
Female	990 (56.3%)	251 (57.8%)	518 (55.5%)	221 (56.5%)	
Education level					
No formal education	575 (32.7%)	171 (39.4%)	288 (30.9%)	116 (29.7%)	0.003
Primary school and above	1,183 (67.3%)	263 (60.6%)	645 (69.1%)	275 (70.3%)	
Place of residence					
Rural	1,142 (65.0%)	294 (67.7%)	574 (61.5%)	274 (70.1%)	0.004
Urban	616 (35.0%)	140 (32.3%)	359 (38.5%)	117 (29.9%)	
Marital status					
Married	1,441 (82.0%)	357 (82.3%)	764 (81.9%)	320 (81.8%)	0.984
Others	317 (18.0%)	77 (17.7%)	169 (18.1%)	71 (18.2%)	
Living relationships					
Living alone	220 (12.5%)	41 (9.4%)	127 (13.6%)	52 (13.3%)	0.083
Living with a partner	1,538 (87.5%)	393 (90.6%)	806 (86.4%)	339 (86.7%)	
Smoking status					
Current smoking	300 (17.1%)	78 (18.0%)	152 (16.3%)	70 (17.9%)	0.657
Others	1,458 (82.9%)	356 (82.0%)	781 (83.7%)	321 (82.1%)	
Alcohol drinking					
Regular drinking	193 (11.0%)	37 (8.5%)	115 (12.3%)	41 (10.5%)	0.105
Others	1,565 (89.0%)	397 (91.5%)	818 (87.7%)	350 (89.5%)	
Household income, CNY					
<3,000 per month	1,293 (73.8%)	332 (76.9%)	672 (72.1%)	289 (74.3%)	0.173
≥3,000 per month	460 (26.2%)	100 (23.1%)	260 (27.9%)	100 (25.7%)	
Baseline BMI, kg/m ²	24.36 (3.36)	24.63 (3.29)	24.64 (3.41)	23.39 (3.16)	<0.001

BMI, body mass index. Weight gain was defined as an increase of $\geq 3\%$ in body weight, and weight loss was defined as a decrease of $\geq 3\%$ in body weight. Weight stability was defined as having a weight change of $< 3\%$ in body weight during the study period.

significant correlation between weight change and change in HDL cholesterol (Table 3).

3.3 Worsening of CV risk factors across different weight change categories

The highest proportion of patients with worsening CV risk factors was found in the weight gain group, where 37.4% of patients had increased HbA1c, 66.0% had increased LDL cholesterol, 64.2% had decreased HDL cholesterol, 55.8% had increased triglycerides, 59.1% had increased total cholesterol, 57.8% had increased systolic BP, and 52.3% had increased diastolic BP. An increasing trend in the proportion of patients with the worsening of HbA1c ($p < 0.001$),

triglycerides ($p < 0.001$), total cholesterol ($p < 0.001$), systolic BP ($p < 0.001$), and diastolic BP ($p = 0.027$) was observed across the three groups from weight loss to weight gain (Figure 1).

3.4 Associations between different weight categories and worsening of CV risk factors

The multivariable logistic regression analysis showed that having a weight loss of $\geq 3\%$ was negatively associated with increased HbA1c (adjusted odds ratio [aOR]=0.698, 95%CI: 0.522-0.933, $p = 0.015$) and increased triglycerides (aOR=0.675, 0.520-0.876, $p = 0.003$) after adjusting for age, sex, baseline BMI, education level, residence

TABLE 2 Medical history and use of medications by different weight change categories.

Variables	All patients (N =1,758)	Weight loss (n=434)	Weight stability (n=933)	Weight gain (n=391)	p-value
Duration of T2DM					
<10 years	1,288 (73.3%)	319 (73.5%)	680 (72.9%)	289 (74.1%)	0.896
≥10 years	469 (26.7%)	115 (26.5%)	253 (27.1%)	101 (25.9%)	
Presence of hypertension					
Yes	725 (41.2%)	192 (44.2%)	397 (42.6%)	136 (34.8%)	0.011
No	1,033 (58.8%)	242 (55.8%)	536 (57.4%)	255 (65.2%)	
Presence of CV disease					
Yes	244 (13.9%)	61 (14.1%)	125 (13.4%)	58 (14.8%)	0.783
No	1,514 (86.1%)	373 (85.9%)	808 (86.6%)	333 (85.2%)	
Use of antihypertensive drugs					
Yes	618 (35.2%)	163 (37.6%)	339 (36.3%)	116 (29.7%)	0.033
No	1,140 (64.8%)	271 (62.4%)	594 (63.7%)	275 (70.3%)	
Use of oral hypoglycaemic drugs					
Yes	1,304 (74.2%)	329 (75.8%)	692 (74.2%)	283 (72.4%)	0.532
No	454 (25.8%)	105 (24.2%)	241 (25.8%)	108 (27.6%)	
Use of insulin					
Yes	179 (10.2%)	34 (7.8%)	107 (11.5%)	38 (9.7%)	0.111
No	1,579 (89.8%)	400 (92.2%)	826 (88.5%)	353 (90.3%)	

T2DM, type 2 diabetes mellitus; CV, cardiovascular. Weight gain was defined as an increase of ≥3% in body weight, and weight loss was defined as a decrease of ≥3% in body weight. Weight stability was defined as having a weight change of <3% in body weight during the study period.

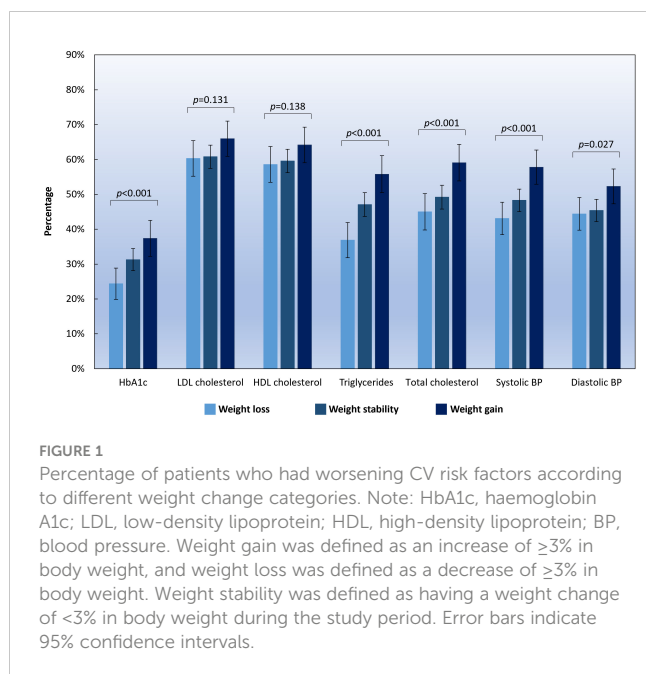
place, marital status, living relationships, household income, smoking status, alcohol drinking, duration of diabetes, antihypertensive medication use, oral hypoglycaemic drugs use, insulin use, and presence of CV comorbidities. Meanwhile, having a weight gain of ≥3% was positively associated with increased HbA1c (aOR=1.347, 1.024-1.772, $p=0.033$), increased triglycerides (aOR=1.491, 1.147-1.938, $p=0.003$), increased total cholesterol (aOR=1.466, 1.127-1.908, $p=0.004$), increased systolic BP (aOR=1.445, 1.129-1.850, $p=0.003$), and increased diastolic BP (aOR=1.345, 1.053-1.718, $p=0.018$) (Figure 2).

TABLE 3 Changes in CV risk factors and their correlations with weight change.

	Baseline		Changes during 2020-2021		Correlation with weight change
	N	Mean ± SD	N	Mean (95%CI)	
Weight, kg	1,758	59.79 ± 10.44	1,758	-0.02 (-0.15, 0.11)	
HbA1c, %	1,658	7.98 ± 2.39	1,503	-0.95 (-1.07, -0.84)†	0.096†
LDL cholesterol, mmol/L	1,659	2.24 ± 0.78	1,505	0.26 (0.22, 0.30)†	0.070*
HDL cholesterol, mmol/L	1,662	1.41 ± 0.65	1,508	-0.07 (-0.11, -0.03)†	-0.023
Triglycerides, mmol/L	1,662	2.19 ± 1.78	1,507	-0.09 (-0.17, -0.004)*	0.133†
Total cholesterol, mmol/L	1,662	5.28 ± 1.39	1,505	0.04 (-0.02, 0.11)	0.070*
Systolic BP, mmHg	1,752	141.46 ± 19.24	1,745	0.76 (-0.14, 1.66)	0.136†
Diastolic BP, mmHg	1,752	84.14 ± 11.18	1,743	-0.12 (-0.69, 0.45)	0.083†

* $p<0.05$, † $p<0.001$.

HbA1c, haemoglobin A1c; LDL, low-density lipoprotein; HDL, high-density lipoprotein; BP, blood pressure.



4 Discussion

4.1 Main findings

We examined changes in body weight and CV risk factors during a one-year follow-up period in a Chinese primary care population with T2DM. Nearly one in four patients had a weight loss of $\geq 3\%$, while slightly above one-fifth of patients had a weight gain of $\geq 3\%$. Significant linear correlations were found between weight change and a set of changes in HbA1c, LDL cholesterol, triglycerides, total cholesterol, and BP. The multivariable logistic regression analysis demonstrated that patients who had a weight loss of $\geq 3\%$ were more likely to prevent the worsening of HbA1c and triglycerides while having a weight gain of $\geq 3\%$ was found to be associated with the worsening of HbA1c, triglycerides, total cholesterol, and BP.

4.2 Relationship with other studies

Data from the United States described a growing toll of diabetes and obesity-related CV disease despite a decline in CV mortality over the past four decades (32). Global estimates of disease burden showed that CV disease attributable to elevated BMI was the main cause of death and disability-adjusted life years, accounting for 2.7 million deaths and 66.3 million disability-adjusted life years (33). Weight gain has been shown to induce early onset and accumulation of vascular risk factors, which are closely linked to cardiometabolic abnormalities such as atherosclerosis (34). Earlier findings from a large population-based cohort study in China suggested that the CV risk started to increase with mildly elevated body weight ($23\text{--}25\text{ kg/m}^2$) (35) – a level that is considered normal weight according to the WHO criteria (36). A cohort study conducted in the American population reported that people with

weight-gain patterns were more prone to have above-goal HbA1c and BP than their counterparts with weight loss (15). This was similarly observed in our study in which having a weight gain of 3% and above was significantly associated with worsening of CV risk factors including HbA1c, triglycerides, total cholesterol, and both systolic and diastolic BP. The results were in line with our expectations and the existing literature which suggested that a progression from non-obese to becoming obese was accompanied by an increment in predicted risk for CV disease in the Japanese community residents (9). It is possible that low-grade inflammation and dysregulation of the endocrine and immune milieu in the adipose tissue could lead to abnormal production of adipokines and inflammatory molecules (37). Previous evidence also suggested a link between weight gain and increased risk of vascular dysfunction in patients with T2DM (38), which implies that physicians should move beyond a simple focus on glycaemic control and takes into account the importance of weight management in diabetes care.

Previous epidemiological studies have established that the rising prevalence of overweight and obesity contributes to the increased incidence of diabetes and CV disease (39–41). Weight loss has been incorporated as one of the major goals of interventions in T2DM patients who are overweight or obese to prevent the development of CV disease. An observational analysis of obese patients with T2DM in the Look AHEAD study showed that weight losses of 5 to $<10\%$ were associated with significant improvements in HbA1c, BP, triglycerides, and HDL cholesterol (17). Our data showed that weight loss of $\geq 3\%$ was strongly associated with improved HbA1c and triglycerides. The benefits of weight loss on other CV risk factors such as total cholesterol and BP were also observed in our study albeit not statistically significant. This may be due to the use of a more conservative threshold level of 3% instead of 5% for determining the meaningful magnitude of weight change in our study given that achieving a greater level of weight loss requires intense interventions (16), which, however, was absent in the present study. It might also be explained by the increased fitness as a result of the long-term lifestyle intervention in the Look AHEAD study, which may improve CV risk factors beyond weight loss alone and further enhance the beneficial effect (42, 43). Nevertheless, we did observe significant associations of weight change with improved HbA1c, triglycerides, total cholesterol, systolic BP, and diastolic BP among patients who had a weight gain of $\geq 3\%$ in our study. This implies the consistency of evidence that relates weight change to CV risk factors.

4.3 Implications for research and practice

Regular monitoring of BP, lipid profiles, and body weight has been emphasised in diabetes management (44, 45). A modest weight loss has been considered beneficial to improving glycaemic control, BP, lipid profiles, and metabolic parameters in T2DM patients (16, 17). Nevertheless, there remain multiple barriers to effective and sustainable weight management. First, it tends to be more difficult to lose weight for people with diabetes compared to those free of diabetes (46). Second, adherence to long-term lifestyle advice such as diet modification and aerobic exercise appears to be

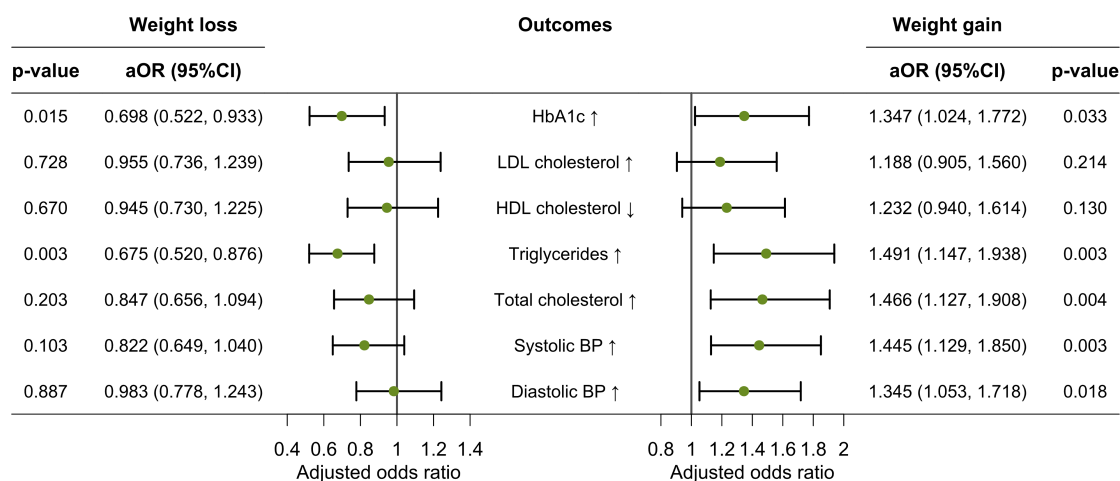


FIGURE 2

Multivariable logistic regression analysis of associations between weight loss/gain and worsening of CV risk factors. Note: aOR, adjusted odds ratio; HbA1c, haemoglobin A1c; LDL, low-density lipoprotein; HDL, high-density lipoprotein; BP, blood pressure. Weight gain was defined as an increase of $\geq 3\%$ in body weight, and weight loss was defined as a decrease of $\geq 3\%$ in body weight during the study period. Error bars indicate 95% confidence intervals.

complex and challenging (47, 48). A meta-analysis has revealed the difficulties in achieving a weight loss of more than 5% in most lifestyle weight-loss interventions (16). Third, certain antidiabetic agents may cause weight gain and thereby exacerbate other CV risk factors associated with T2DM (49). Our study suggested a beneficial impact of weight loss of $\geq 3\%$ on CV risk factors. In the Chinese guideline on prevention and treatment of T2DM, achieving a weight loss of 3% to 5% has been considered fundamental to weight management for overweight or obese adults with T2DM (45). Previous real-world studies exhibited that in patients who were newly treated for T2DM, those with weight loss of $\geq 3\%$ were more likely to achieve better glycaemic control (50). It is worth noting that the main purpose of our study was not to explore the threshold level *per se* for weight change. Instead, we are interested in understanding whether having a weight loss at a modest level that is culturally feasible in real-world settings could be associated with beneficial outcomes. Given the worsening of CV risk factors due to weight gain, regular monitoring of body weight should not be neglected in people whose BMI falls within the normal range. Maintaining optimal weight control shall necessitate appropriately designed health communication efforts (51), which could be made *via* interpersonal or mass media channels to reinforce diet, physical activity, and behavioural changes (52). Existing approaches for weight management advocate a cohesive engagement of primary care practitioners and multidisciplinary teams to overcome a variety of obstacles that hinder effective nonpharmacologic and pharmacologic treatment (53–55).

4.4 Strengths and weaknesses of the study

We presented primary care longitudinal data that reinforced the primacy of weight management as integral to diabetes care, while extending the existing evidence to a Chinese population with a particular focus on the changes in body weight and its association

with changes in CV risk factors in the real-world setting. Unlike many other studies conducted in the west, nearly half of participants in our study had their BMI falling within the normal range at baseline. Both urban and rural participants were included to take into account the socioeconomic disparities. A broad range of information on patients' demographics, lifestyle behaviours, medical history, current use of antihypertensive drugs and glucose-lowering agents, presence of CV comorbidities, and clinical parameters was collected. All clinical measurements including physical examination and laboratory tests were performed under routine check-up procedures with quality control. However, our study had several limitations. First, lifestyle behaviours were considered confounding factors and were measured in a simplified dichotomous manner, which precluded the evaluation of the frequency and intensity of physical exercise, and intake of dietary compositions (56, 57). It is also possible that smoking cessation could be accompanied by weight gain, and may impact the association between weight gain and changes in CV outcomes (58, 59). Second, we did not have information on how weight loss was achieved, nor whether an individual's weight loss was intentional or secondary to disease. As indicated by earlier evidence, it is reasonable to assume a greater benefit of weight loss in patients who had the intention to lose weight (60). Third, we did not gather information on the fluctuation of weight during the period before baseline, and thus we cannot rule out the possibility that an individual was gaining or losing weight at study entry. Fourth, although the use of antihypertensive drugs, oral hypoglycaemic drugs and insulin was taken into account in the regression analysis, we were not able to determine whether there were changes either in diabetes medication (e.g., initiation of SGLT2i or GLP-1 receptor agonists) or in concomitant medications that might have affected weight or CV risk factors (e.g., initiation of or change in the dose of statin) during the course of this study. Last but not least, associations between the magnitude of weight change and subsequent CV outcomes may vary after the one-year follow-up period, which may warrant evidence from further long-term investigations with the assistance of wearable devices, digital eHealth platforms, and remote

patient monitoring tools to guide clinical decisions in primary care (61).

5 Conclusion

Our data from a primary care population of T2DM patients demonstrated the longitudinal changes in body weight along with a set of concurrent changes in CV risk factors in the real-world setting. Patients who had a weight loss of $\geq 3\%$ were more likely to prevent the worsening of HbA1c and triglycerides, while those who had a weight gain of $\geq 3\%$ tended to have worsened HbA1c, lipid profiles, and blood pressure. Our results suggested the concurrent need for weight loss intervention among patients who are overweight or obese and weight gain prevention among patients whose body weight falls within the normal range in the context of community-based diabetes management.

Data availability statement

The raw data supporting the conclusions of this article are available on reasonable request from the corresponding authors.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee at Zhongshan Ophthalmic Center, Sun Yat-Sen University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

Conceptualisation: Y-YL, HHXW, and YTL; data curation: WH and YTL; formal analysis: Y-YL; validation: Y-MY; methodology: Y-

YL and HHXW; project administration: YTL; supervision: WH and HHXW; writing—original draft preparation: Y-YL, HHXW, and YTL; writing—review and editing: SZ, HC, and JH. All authors contributed to the article and approved the submitted version.

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Conflict of interest

Author JH was employed by Digital Education Holdings Ltd.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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