

## ORIGINAL ARTICLE

# Differences in weight change trajectory patterns in a publicly funded adult weight management centre

J. L. Kuk<sup>1</sup> and S. Wharton<sup>1,2</sup>

<sup>1</sup>School of Kinesiology and Health Science, York University, Toronto, Canada; <sup>2</sup>The Wharton Medical Clinic, Hamilton, Canada

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Address for correspondence: Sean Wharton, York University, Sherman Health Science Research Centre, Room 2002, 4700 Keele Street, Toronto, ON M3J 1P3, Canada. E-mail: wharton@whartonmedicalclinic.com

## Summary

### Objective

To describe differences in weight loss (WL) trajectory patterns at a publicly funded clinical weight management centre.

### Methods

Groups with differences in the attainment of a 5% total body WL and percentage WL patterns over time were identified in 7,121 patients who attended a physician lead multi-disciplinary clinical lifestyle weight management that predominantly focused on education and diet counselling. Resultant health differences were examined.

### Results

Patients had  $3.2 \pm 6.3\%$  WL with 35% of patients achieving and maintaining a 5% WL. Half of these patients achieved the 5% WL within 6 months, while the other half had a more gradual approach. Another 10% achieved 5% WL, but regained weight after 6 months. There were seven distinct WL patterns identified: LargeWL (Mean WL:  $21.2 \pm 8.1\%$ ; Probability of group membership (PGM): 2.4%), ModerateWL ( $15.1 \pm 5.1\%$  WL; 5.4% PGM), SlowWL ( $6.7 \pm 3.2\%$  WL; 20.1% PGM) and MinimalWL ( $2.4 \pm 2.2\%$  WL; 34.6% PGM), WL Regain ( $9.4 \pm 3.5\%$  WL; 8.2% PGM), Weight Stable ( $1.2 \pm 3.2\%$  WL; 28.5% PGM) and Weight Gain ( $18.4 \pm 11.2\%$  WG; 0.8% PGM) groups. Improvements in blood pressure, lipids and glucose were generally related to the magnitude of WL achieved more than the pattern or speed of WL.

### Conclusions

There are large differences in the absolute WL attained and the pattern of WL during a publicly funded weight management program. Changes in clinical health markers appear to be more strongly related with the absolute WL attained as opposed to patterns of weight change. © 2016 The Authors. Obesity Science & Practice published by John Wiley & Sons Ltd, World Obesity and The Obesity Society.

**Keywords:** Cardiovascular risk factors, lifestyle intervention, obesity, weight management.

## Introduction

Obesity is associated with increased morbidity and mortality, and it is well established that even a modest weight loss (WL) of 5% is associated with health benefits (1–3). Lifestyle is a cornerstone of weight management and is reported to be associated with a 5–10% WL over 6–12 months (4), but differences in the pattern of WL and longer term weight maintenance are most commonly

described as the difference between two time points, and studies rarely report beyond four time points. This means that differences in how individuals lose weight and the prevalence of different WL patterns are not regularly described. Currently, the few studies that examine WL trajectories use treatment (5,6) or outcome based groupings (7,8). However, these approaches assume that all individuals who receive a given treatment have a similar efficacy or that those who had a similar program

effectiveness arrive at their outcome through a similar pattern. Latent class trajectory analysis allows for the identification of multiple distinct longitudinal WL patterns, without a priori assumptions about how individuals should be grouped. This novel approach would allow for different groups of individuals who attain similar weight outcomes through different patterns of weight change to be identified. This may be important given the disputed health effects of weight cycling. However, we are unaware of a study that has used latent trajectory analyses to examine differences in WL patterns.

The purpose of the present study is to describe differences in WL trajectory patterns over 7.5 years of weight management at a publicly funded adult clinical weight management centre. In addition, demographic factors that are related to differences in these WL patterns and resultant health changes will be examined.

## Materials and methods

### Study population

The study population included 7,121 overweight and obese adults who attended the Wharton Medical Clinic (WMC) between July 2008 and Dec 2014. Data used was obtained from electronic medical files. Participants were excluded if they only attended the clinic once, and thus did not have WL data. All participants gave their written consent for the use of their medical data for research purposes and were informed that their decision to participate would not influence their medical treatment at WMC. Participants did not receive any form of stipends. All methods were approved by the York University Research Ethics Board (Ethics Certificate #: 2013 – 123).

The WMC has been described previously in detail (9,10), but briefly, it is a physician referral-based clinic designed to educate patients about weight management and enable patients to implement strategies to improve their health. The program is delivered by a team of physicians, dietitians, behavioural therapists and exercise specialists. Patients attend the clinic on a monthly basis or as needed to have individual meetings with bariatric educators to discuss personalized weight management strategies, dietary plans and physical activity options.

### Nutrition intervention

All patients have a metabolic rate assessment via indirect calorimeter and prediction using the Mifflin St. Joer equation (11) to assist in determining appropriate caloric targets for their meal plan. Patients are prescribed a 500 kcal daily deficit to attain a gradual WL of 1–2 lbs/week. Meal plans range from approximately 1,200

to 2,500 kcal per day. Patients are encouraged to eat six times daily, with three meals and three snacks. Macronutrient content of the meals follows the Health Canada and American Dietitians Association recommendations for protein (20 – 30%), fat (20 – 30%) and carbohydrates (40 – 60%). Meal plans are adjusted based on medical comorbidities, including renal failure.

### Activity recommendations

All patients are advised to follow the Canadian Physical Activity Guidelines recommendations of 150 min of physical activity per week. Slow and incremental activity is suggested, and activity is adjusted based on comorbid conditions, including osteoarthritis and muscular disorder.

### Mental health counselling

Patients with mental health conditions, eating disorders and emotional eating behaviours are counselled on these conditions. Referrals to psychiatry and eating disorder programs are also given to patients requiring these interventions.

### Medications and surgical interventions

Patients who fit the criteria for medication or surgical intervention for obesity are given information and recommendations for these interventions. The WMC prescribes the medications and provides follow-up care for these patients. The WMC refers and prepares patients for bariatric surgery and follows them post-operatively.

### Follow-up and maintenance

All patients are followed for as long as they choose to receive care. There is no discharge from the clinic and long-term maintenance and management of relapse care are provided for all patients. Maintenance involves nutrition, activity, counselling and medical and surgical support as needed.

Patients also undergo a standard battery of clinical tests including standard blood measures, resting metabolic rate, anthropometrics and cardiac testing. Patients meet with physicians to discuss medication options, interest in bariatric surgery and any obesity related comorbidities. If indicated, patients are referred for additional tests, to other medical professionals. Monthly group workshops are also offered on various weight management topics administered by MDs, dietitians, behavioural therapists and exercise specialists. The clinic operates

within the Ontario Health Insurance Plan, and all services are provided at no charge to the patient.

Body weight (BW) was measured by staff at each patient visit on a calibrated MedWeight, MS-2510 Digital High Capacity Platform Scales (Itin Scale Co, Inc., NY). Percent weight reduction was calculated as  $[(\text{initial BW} - \text{final observed BW}) / \text{initial BW}] \times 100\%$ . Clinically significant WL was defined as a minimum of 5% reduction in initial BW. Blood pressure (BP) was assessed at most patient visits. Fasting glucose, triglycerides (TG), low-density lipoprotein (LDL) and high-density lipoprotein (HDL) were assessed using standard clinical methods in a subsample of participants ( $n = 2,847$  to 4,696). Patients self-identified their ethnicity as White, Black, South Asian, East Asian or Other, and were categorized as White or Other for the purposes of these analyses.

### Statistical analyses

A mixed-model, semi-parametric group-based modelling technique was used to explore group differences in the shape of the trajectory of weight changes using a customized SAS macro (PROC TRAJ) (12). This allows for the identification of multiple distinct pathways or patterns, while accounting for unobserved heterogeneity in the data (13). All weight changes trajectories were modelled as a function of treatment time to identify: (i) the probability of losing at least 5% of their initial body weight and (ii) percent WL. Similar findings were observed with absolute WL, and so only percent WL values are reported here. The Bayesian Information Criterion (BIC), posterior probabilities and descriptive statistics were used to evaluate the fit of the most parsimonious model (12,14). Models were chosen based on the lowest BIC or when there was no new meaningful trajectory patterns identified. Once all participants had been assigned to a trajectory group, group-level profiles, age, sex and initial body mass index (BMI) were examined as independent group predictors relative to the referent group (Group 1). Simple group

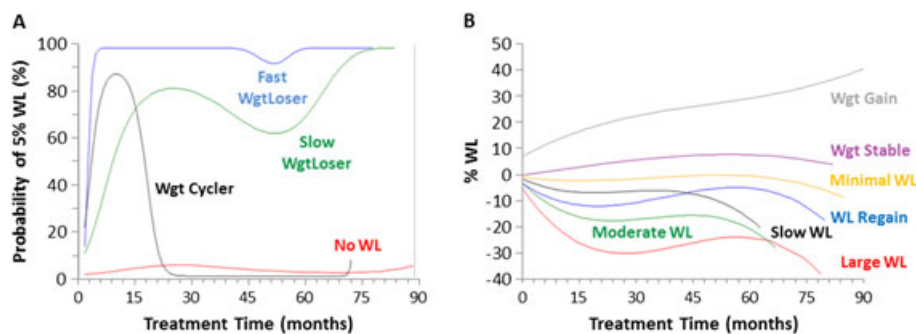
differences in the patient characteristics at baseline were determined using ANOVA and chi-square tests with Bonferroni post hoc tests.

Because metabolic variables were not always obtained at the onset of treatment, values at the last available measure were used to impute missing baseline values (50 imputations) (Supplementary Table). Individuals with no recorded values were excluded from each respective analysis. Proc Mianalyze was used with the imputed data to determine differences in metabolic changes between trajectory groups with adjustment for age, sex, initial BMI (or weight change), treatment time, medication use (yes/no) and the respective baseline metabolic value. All statistical analyses were conducted using SAS 9.4 (SAS Institute, Cary, NC, USA). Statistical significance was established at  $P < 0.05$ .

### Results

Within the entire cohort, patients were  $51.1 \pm 13.0$  years of age, had a BMI of  $40.3 \pm 7.7 \text{ kg/m}^2$ , with  $2.3 \pm 1.3$  health risk factors at baseline. Patients attended the clinic for an average  $12.0 \pm 14.6$  months with 50% of patients attending the clinic for  $>6$  months, 25% of patients attending  $>14$  months and 10% of patients attending  $>33$  months. Patients had  $7 \pm 6$  visits (range 2 to 53 visits) with 50% of patients attended at least once per month and had an average WL of  $3.6 \pm 7.7 \text{ kg}$  ( $3.2 \pm 6.3\%$ ).

When examining trajectory WL patterns for the likelihood of achieving a 5%WL, the four group model emerged as the most parsimonious. The groups were descriptively named with the probability of group membership as follows: (i) noWL ( $54.4 \pm 0.9\%$ —i.e. patients at the clinic have a 54% chance of being in this group); (ii) Slow Weight Loser (WgtLoser— $17.7 \pm 0.8\%$ ); (iii) Fast WgtLoser ( $18.1 \pm 0.7\%$ ); and (iv) WgtCycler ( $9.8 \pm 0.7\%$ ) (Figure 1A). Participant characteristics for the four group model are presented in Table 1.



**Figure 1** Trajectory patterns for achieving a 5%WL (A) and %WL (B) over treatment time. WL = weight loss.

**Table 1** Participant characteristics in trajectory groups for attaining a 5% weight loss

Group	No WL	Slow WgtLoser	Fast WgtLoser	Wgt Cyclor
Probability of group membership	54.4 ± 0.9%	17.7 ± 0.8%	18.1 ± 0.7%	9.8 ± 0.7%
Age (years)	49.9 ± 13.0 <sup>b-d</sup>	52.9 ± 12.8 <sup>a</sup>	53.0 ± 12.7 <sup>a</sup>	55.6 ± 12.8 <sup>a-c</sup>
Sex (%male)	24.9	28.3	27.5	26.4
Ethnicity (%White)	82.7 <sup>b-d</sup>	88.3 <sup>a</sup>	90.7 <sup>a</sup>	90.2 <sup>a</sup>
BMI (kg/m <sup>2</sup> )	40.1 ± 7.6 <sup>b</sup>	41.3 ± 8.1 <sup>a</sup>	40.5 ± 7.8	40.5 ± 7.8
Health risk factors (#)	2.3 ± 1.3	2.4 ± 1.4	2.3 ± 1.4	2.5 ± 1.2
Weight change (kg)	-0.4 ± 4.3 <sup>b-d</sup>	-7.7 ± 7.1 <sup>a,c,d</sup>	-12.6 ± 8.9 <sup>a</sup>	-3.2 ± 6.1 <sup>a-c</sup>
Weight change (%)	-0.3 ± 3.9 <sup>b-d</sup>	-6.6 ± 5.3 <sup>a,c,d</sup>	-10.9 ± 5.9 <sup>a</sup>	-2.9 ± 5.2 <sup>a-c</sup>
Treatment time (months)	9 ± 13 <sup>b-d</sup>	22 ± 18 <sup>a,c</sup>	13 ± 14 <sup>a,b,d</sup>	23 ± 17 <sup>a,c</sup>

Values are mean ± SD or %.

<sup>a</sup>= Significant difference from noWL ( $P < 0.05$ ).

<sup>b</sup>= Significant difference from Slow WgtLoser ( $P < 0.05$ ).

<sup>c</sup>= Significant difference from Fast WgtLoser ( $P < 0.05$ ).

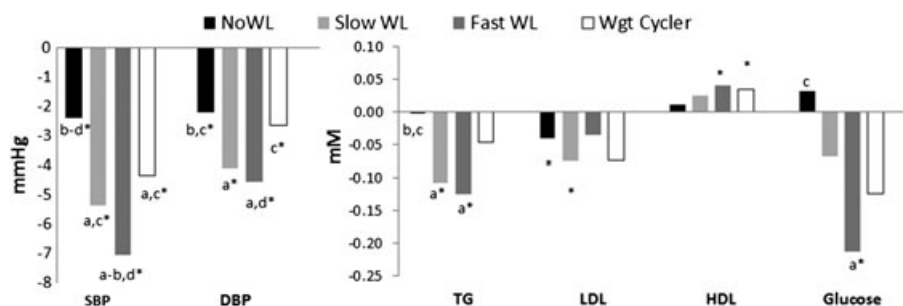
<sup>d</sup>= Significant difference from Wgt Cyclor ( $P < 0.05$ ).

In general, patients in the noWL group were younger and were less likely to be White than Slow WgtLoser, Fast WgtLoser and WgtCyclor ( $P < 0.05$ ), but with minimal differences in initial BMI, sex or metabolic status. Slow and Fast WgtLoser groups were able to achieve 6.6% and 10.9% WL respectively. Similar to Fast WgtLoser, a large proportion of WgtCyclor (~90%; Figure 1A) was able to achieve a 5% WL, but then regained weight after 6 months. Interestingly, Slow WgtLoser and WgtCyclor attended the clinic for a longer period of time as compared to the noWL and Fast WgtLoser groups. Age was an independent predictor of group membership, while BMI was only an independent predictor of being in the WgtLoser groups as compared to noWL. Sex was not predictive of group membership.

The noWL group tended to have subtly worse lipid profiles, higher fasting glucose and lower BP than the other groups at the onset of treatment (data not shown). The changes in BP, lipids and glucose for each 5% WL

trajectory group adjusted for age, sex, initial BMI, treatment time, medication use and the respective baseline metabolic value are shown in Figure 2. Slow and Fast WgtLoser had superior BP and TG improvements as compared to noWL. Fast WgtLoser also had significantly greater improvements in glucose compared with noWL, with no significant between group differences in LDL and HDL. Although Fast WgtLoser tended to have greater improvements in health than Slow WgtLoser this did not reach statistical significance, except for systolic BP (SBP) ( $P = 0.01$ ). However, after adjustment for differences in WL, there were no differences in any of the metabolic improvements between Slow and Fast WgtLoser groups ( $P > 0.05$ ).

When examining trajectory patterns for percent weight change, the seven group model emerged as the most parsimonious: (i) LargeWL (representing 2.4 ± 0.2% of the sample); (ii) ModerateWL (5.4 ± 0.4%); (iii) WLRegain (8.2 ± 0.6%); (iv) SlowWL (20.1 ± 0.9%); (v) MinimalWL

**Figure 2** Differences in metabolic changes for trajectory groups achieving a 5% weight loss.

Adjusted for age, sex, BMI, treatment time, medication use and the respective baseline metabolic value.

\*within group change ( $P < 0.05$ )

a = versus noWL ( $P < 0.05$ )

b = versus Slow WgtLoser

c = versus Fast WgtLoser

d = versus Wgt Cyclor

**Table 2** Participant characteristics in trajectory groups for % weight change

Group	Large WL	Moderate WL	Regain WL	Slow WL	Minimal WL	Wgt stable	Wgt gain
Group membership probability (%)	2.4 ± 0.2%	5.4 ± 0.4%	8.2 ± 0.6%	20.1 ± 0.9%	34.6 ± 1.2%	28.5 ± 1.1%	0.8 ± 0.1%
<i>n</i>	165	291	481	1,131	2,625	2367	54
Age (years)	50.6 ± 12.5 <sup>a,f</sup>	52.7 ± 13.6 <sup>c,e,f</sup>	56.3 ± 11.8 <sup>a,b,d,f,g</sup>	53.0 ± 12.7 <sup>c,e,f</sup>	55.2 ± 11.5 <sup>a,b,d,g</sup>	44.4 ± 12.3 <sup>a,f</sup>	48.3 ± 14.4 <sup>c-e</sup>
Sex (%male)	41.8 <sup>b,d-g</sup>	18.6 <sup>a,c,e</sup>	35.8 <sup>b,d,f</sup>	19.4 <sup>a,c,e</sup>	32.7 <sup>a,b,d,f</sup>	19.0 <sup>a,c,e</sup>	24.1 <sup>a</sup>
Ethnicity (%White)	92.2 <sup>e-g</sup>	89.5 <sup>f</sup>	88.7 <sup>f</sup>	90.2 <sup>e-g</sup>	86.0 <sup>a,d,f</sup>	80.3 <sup>a-e</sup>	79.2 <sup>a,b,d</sup>
BMI (kg/m <sup>2</sup> )	43.9 ± 9.3 <sup>b-g</sup>	40.4 ± 7.7 <sup>a</sup>	40.5 ± 7.8 <sup>a,g</sup>	40.5 ± 7.6 <sup>a,g</sup>	40.6 ± 7.9 <sup>a,f,g</sup>	39.7 ± 7.4 <sup>a,e,g</sup>	35.5 ± 7.7 <sup>a-f</sup>
Health risk factors (#)	2.3 ± 1.3	2.3 ± 1.3	2.5 ± 1.2	2.4 ± 1.4	2.5 ± 1.3 <sup>g</sup>	2.1 ± 1.3 <sup>f</sup>	1.9 ± 0.9
Weight change (kg)	-27.0 ± 15.5 <sup>b-g</sup>	-17.0 ± 7.8 <sup>a,c-g</sup>	-10.7 ± 4.9 <sup>a,b,d-g</sup>	-7.5 ± 4.2 <sup>a-c,e-g</sup>	-2.7 ± 2.7 <sup>a-d,f-g</sup>	1.4 ± 3.8 <sup>a-e,g</sup>	18.1 ± 11.6 <sup>a-f</sup>
Weight change (%)	-21.2 ± 8.1 <sup>b-g</sup>	-15.1 ± 5.1 <sup>a,c-g</sup>	-9.4 ± 3.5 <sup>a,b,d-g</sup>	-6.7 ± 3.2 <sup>a-c,e-g</sup>	-2.4 ± 2.2 <sup>a-d,f-g</sup>	1.2 ± 3.2 <sup>a-e,g</sup>	18.4 ± 11.2 <sup>a-f</sup>
Treatment time (mo)	13 ± 14 <sup>b</sup>	19 ± 17 <sup>d-g</sup>	20 ± 18 <sup>a,b,d-g</sup>	14 ± 13 <sup>a-c,e-g</sup>	11 ± 14 <sup>a-d,f-g</sup>	10 ± 13 <sup>a-e,g</sup>	27 ± 24 <sup>a-f</sup>

Values are mean ± SD or %.

<sup>a</sup>= Significant difference from Large WL ( $P < 0.05$ ).

<sup>b</sup>= Significant difference from Moderate WL ( $P < 0.05$ ).

<sup>c</sup>= Significant difference from Regain WL ( $P < 0.05$ ).

<sup>d</sup>= Significant difference from Slow WL ( $P < 0.05$ ).

<sup>e</sup>= Significant difference from Minimal WL ( $P < 0.05$ ).

<sup>f</sup>= Significant difference from Wgt Stable ( $P < 0.05$ ).

<sup>g</sup>= Significant difference from Wgt Gain ( $P < 0.05$ ).

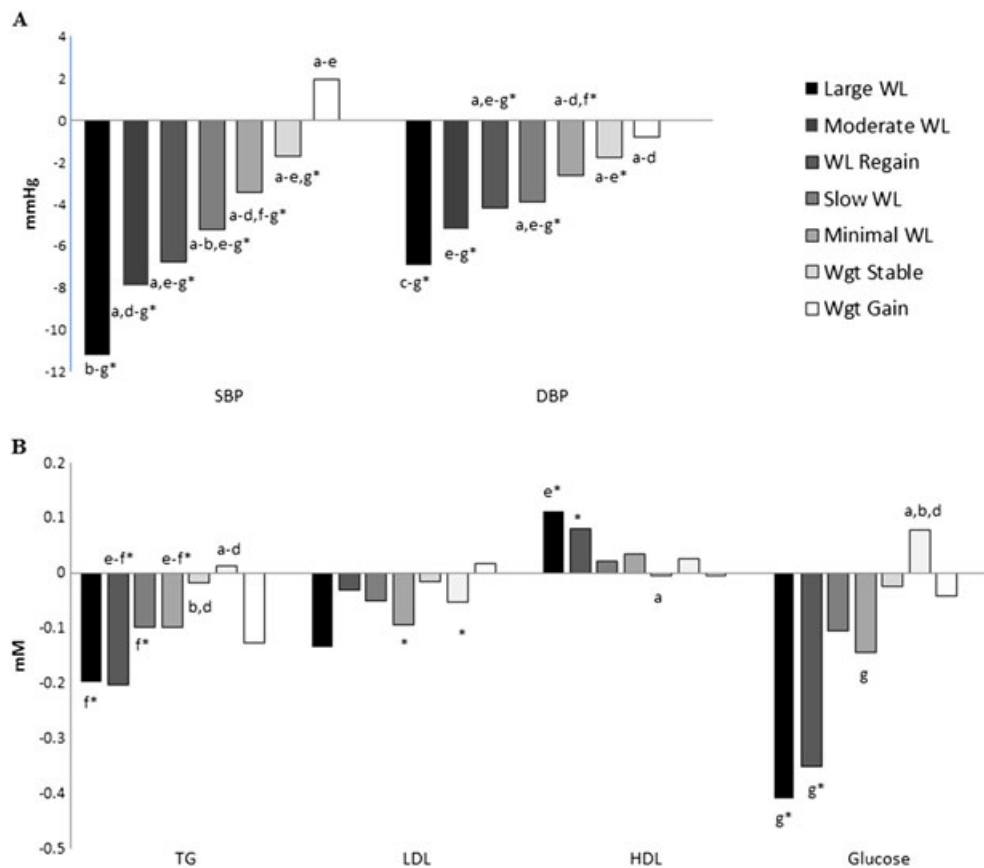
(34.6 ± 1.2%); (vi) WgtStable (28.5 ± 1.1%); and (vii) WgtGain (0.8 ± 0.1%) (Figure 1B). Individuals in the WL groups were younger than the WLRegain group, but older than those in WgtStable and WgtGain groups (Table 2). WgtGain had the lowest initial BMI, the lowest proportion of White individuals and the longest treatment time (27 months), while LargeWL had the highest initial BMI, the highest proportion of White individuals, and a relatively shorter treatment time (13 months). BMI and male sex were all positively and independently associated with being in the LargeWL group. Age was inconsistently associated with group membership.

WgtStable and WgtGain groups tended to have slightly better baseline BP, but with no consistent pattern of group differences for the lipid or glucose variables (data not shown). BP improvements were greater in groups with greater overall WL adjusted for age, sex, initial BMI, treatment time, medication use and the respective baseline metabolic value (Figure 3A). TG and glucose improvements also tended to be greater in the WL groups than WgtStable, with minimal differences in LDL and HDL (Figure 3B). Adjustment for final WL attained instead of initial BMI abolished most of the significant group differences in metabolic changes (data not shown).

## Discussion

Our study expands on traditional examinations of WL, by illustrating not only the patterns of weight change associated with attending a publicly funded clinical weight management program, but also how commonly these weight change patterns occur and the metabolic changes that are associated with these weight change patterns. We observe that there are large variations in the absolute WL, how quickly that WL is attained, and whether or not that WL is maintained over time. However, health changes appear to be more strongly related with the absolute WL attained as opposed to patterns of weight change.

Current weight management guidelines stress the importance of attaining a 5% WL to achieve health benefits (1). Indeed, the Fast and Slow WgtLoser trajectory groups had a large proportion of patients who attained 5%WL, and had significant improvements in several health factors. Although Fast WgtLoser tended to have larger health improvements than Slow WgtLoser, this only reached statistical significance for SBP. We are only aware of a lone study in 10 postmenopausal women that has examined the effect of WL rate on health risk factors (15). That study did not observe any differences in



**Figure 3** Differences in metabolic changes for percent weight loss trajectory groups. Adjusted for age, sex, BMI, treatment time, medication use and the respective baseline metabolic value.

\*within group change ( $P < 0.05$ )

a = versus LargeWL ( $P < 0.05$ )

b = versus ModerateWL

c = versus WL Regain

d = versus SlowWL

e = versus MinimalWL

f = versus WgtStable

g = versus WgtGain

health change between fast and slow WL, but may have been underpowered. However, in accordance with others (16), faster WL is associated with greater WL overall as compared to slower rates of WL, but whether the rate of WL results in differential effects on health warrants further investigation. Interestingly, the currently recommended 1–2 lb/wk WL was created to reduce the risk for gallstone formation and not because of associations with cardiovascular or diabetes health outcomes (17).

Unexpectedly, NoWL and WgtCycler groups also had significant improvements in BP despite not achieving the 5%WL target by the end of the study. We and others (18,19) have previously demonstrated that clinically relevant health improvements can occur even in the absence of WL. This may be associated with improvement in the quality of diet (20–22) and incorporation of daily physical

activity (23), both of which are associated with health benefits independent of weight change (24). Further, this may be reflective of medication changes, and although we adjusted for medication use, this may not have fully accounted for its effects. Nevertheless, this research together with previous literature suggests that health and obesity may not necessarily track together, and that achieving the 5%WL goal may not necessarily be required for health benefits.

The short and long-term effectiveness of weight management programs have been previously documented (25–29). Most studies use the pragmatic approach in examining the mean absolute changes, with a small subset examining changes at a few intermediate time points during the intervention. Latent trajectory analyses cluster groups of individuals with similar patterns of weight

change, with the flexibility to model both linear and non-linear changes over time (12,14). This is only possible with larger datasets with multiple measures over time, and can be used to assess differences in the pattern of weight changes that may be missed when only examining change scores, or WL trajectories that use a priori groups (5–8). For example, the entire sample of patients as a whole lost 3.6 kg or 3.2% of their initial body weight; however, after separating the patients into the distinct clusters, several patterns of weight change emerged with several different weight outcomes. In fact, only 35% of the population had a WL in this 3% range, while approximately 8% of the study sample (Moderate and Large WL groups) had mean weight reductions of 15–21%. However, when these groups are followed over time, the mean WL attained for individuals that remain in treatment after 2 years is approximately 20 and 30% respectively (Figure 1B), values that are comparable to bariatric surgery (30).

Very few lifestyle interventions have been able to induce a WL of greater than 15% without the use of very low calorie diets, and none over such a long follow-up (31). This is important as health improvements based on lifestyle interventions are largely related to the magnitude of lipid and BP improvements (32). Impressively, BP reductions observed in Moderate and Large WL groups are in par with those observed with several types of hypertension medications (33–36). However, improvements in fasting glucose were inferior to that typically seen with diabetes medications, but are likely in part because of basement effects in patients without diabetes (37,38). It is unclear what factors distinguish this unique group of obese patients, and future research may focus on genetic, behavioural and environmental factors.

We also observed that 28% of patients (WLRegain and SlowWL) attained a 7.5 to 10.7%WL which is comparable with lifestyle weight management interventions reported in the literature (4). SlowWL had steady WL, while WLRegain had a bout of WL that was followed by weight regain and another WL. Thus, depending on the time point in question, the WLRegain group had a mean WL ranging between 5 and 10%. Although, WLRegain had greater mean WL than SlowWL, both groups had similar final WL attainments using the trajectory modelling. This may explain in part why there were no differences in metabolic changes between groups. Weight cycling has inconsistently reported to be associated with deleterious changes in metabolic health independent of body weight (39). The degree of weight regain observed here is smaller than what is typically observed in studies that end treatments after a predetermined length (31), suggesting that sustained care is associated with better maintenance of WL outcomes. This may indicate that obesity

management should be reframed to be a chronic lifelong therapy as opposed to a finite program of predetermined length. Under the Transtheoretical Model (40), relapse is thought to be an inevitable part of any behaviour modification and should be planned for in the treatment strategy. Given our obesogenic environment, expecting that 6–12 month interventions will undo a lifetime of practices and that these newly minted behaviours will persist lifelong is likely unrealistic, and is reflected in the poor weight maintenance seen in studies that adopt this finite treatment model (31).

The remaining 28.5% of the patient cohort were weight stable and a small minority of patients (0.8%) experienced a very significant weight gain. It is unclear why these patients gained weight, but they tended to be younger, have a lower BMI, were more likely to be non-White and had the longest mean treatment time of all trajectory groups. This may indicate that patients were struggling with other issues that may have interfered with their WL goal or were simply non-compliant. Indeed, there are several conditions and pharmacological treatments that result in weight gain, such as certain medications for mental disorders (41), diabetes medications (42) and anti-hypertensives (43). Further, there may be a number of factors that could impair their ability to comply to treatment such as stress, finances, work, family or health. Alternatively, patients could be in the 'Contemplation' or even 'Precontemplation' stages of the Transtheoretical Model, and may be present at the clinic simply because they were referred by their physician or other external reasons, but are not ready to make the behaviour changes promoted at the clinic. For these patients, the reasons 'why' the individual should adopt behaviour change should be stressed until they are ready to engage. Interestingly, despite the large weight gain, there were very few negative metabolic changes observed, although we may have been underpowered despite our large study sample as this group was less than 1% of the patient population ( $n = 54$ ).

Strengths and limitations of the current study warrant mention. First, although weight changes and BP were assessed frequently throughout the intervention, lipids and glucose were not, and thus we were less certain about the true changes in these factors as compared to body weight and BP. Second, although treatment follow-up extended over 7.5 years, the average follow-up lengths were generally less than 2 years, and the weight and health changes after leaving the clinic are unclear. We are unsure if these observations seen here would hold true with other methods of WL such as surgery or medications. Further, there are many factors that can influence health independent of WL that may have obscured our ability to examine the independent effect

of WL patterns on health. Our study sample consisted of patients from a publicly funded weight management clinic that was predominately middle aged women of White ethnicity, and the applicability of these findings to other demographics is unclear. Finally, as this was mainly individualized clinical weight management care, we cannot say for certain what specific intervention components or external factors lead to the weight or health changes observed.

In summary, we demonstrate that there are several different patterns of WL observed in patients attending a publicly funded weight management program. However, differences in health changes appear to be more closely related with the absolute WL achieved than the pattern of WL. Nevertheless, those with faster rates of WL tended to have greater WL overall and superior health improvements. Thus, future research may also wish to consider the speed and pattern of weight change when examining health consequences.

## Conflict of interest

SW is the Medical Director; JLK held an industry grant by the Mitacs-Accelerate internship program in partnership with the Wharton Medical Clinic. This study was supported by a grant from the Canadian Institutes of Health Research (#131594) to JLK. Funders had no role in this study.

## Author roles

The authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. JLK wrote the manuscript and analysed the data. SW and JLK collected the data and SW revised the manuscript for important intellectual content. All authors contributed to the concept and design of the study, interpretation of the data and had approval of the final submitted version of the manuscript.

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