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Perceived barriers to physical activity during and after a behavioural weight loss programme

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Summary

Background: Most adults with overweight/obesity participating in behavioural weight loss (BWL) programmes never achieve prescribed physical activity (PA) levels. This study examined changes in PA barriers, their relationships with accelerometer-measured PA during and after a 12-month BWL programme, and associations between PA barriers and participant characteristics.

Methods: Adults (N = 283) in a BWL programme completed the Barriers to Being Active Quiz, a 21-item self-report measure that assesses seven perceived PA barriers, and they wore an accelerometer for seven consecutive days at baseline and at 6 (midtreatment), 12 (end of treatment), 18 (6-mo follow-up), and 24 months (12-mo follow-up). Weight and height were measured, and demographic information was collected at baseline.

Results: Repeated-measures analyses of variance (ANOVAs) revealed a significant quadratic effect of time on total PA barriers, $P < .001$, such that PA barriers decreased by midtreatment, remained below baseline levels by end of treatment, but increased to near-baseline levels by follow-up. Perceived PA barriers were negatively associated with baseline moderate-to-vigorous PA (MVPA), $P < .001$, and decreases in perceived PA barriers were related to greater MVPA at 6 ($P = .004$), 12 ($P < .001$), and 24 months ($P = .007$). Participants who were younger, $P = .02$, and white, $P = .009$, reported more baseline barriers.

Conclusions: Perceived PA barriers meaningfully decreased during BWL treatment, which in turn was associated with greater MVPA. This pattern suggests that, on average, BWL effectively addresses perceived PA barriers, which contributes to increased PA. Future research should identify interventions to maintain decreases in barriers after end of treatment.

KEYWORDS
barriers, moderate-to-vigorous physical activity, obesity

1 | INTRODUCTION

Behavioural weight loss (BWL) programmes, the gold standard behavioural interventions for weight reduction, teach strategies for decreasing calorie intake and increasing calorie expenditure via physical activity (PA) to produce and maintain weight loss.[1] The target PA prescription in BWL programmes is typically between 150 and 300 min/wk^{-1} of moderate-to-vigorous PA (MVPA),[2-4] as this level of MVPA has been associated with better weight loss maintenance.[5] Regular PA is also associated with lowered risk for many obesity-related diseases, including cardiovascular disease and cancer.[6,7] Despite PA's importance for overall health and weight control, a minority of adults with overweight or obesity meet national PA guidelines (ie, 1-3% using former national guidelines of 150 min/wk^{-1} of *bouted* MVPA and 13-24% using current national guideline of 150 min/wk^{-1} of *total* MVPA),[8-10] and rates of PA adherence are low in those participating in BWL programmes (eg, 21% at 1 y and 12% at 4 y in the Look AHEAD trial).[11-13] Understanding the barriers to engaging in PA in this population is crucial to improve public health.

A substantial amount of research has examined barriers to PA in the general population of adults with overweight or obesity.[14] This research, which has largely been cross-sectional and conducted in community samples (ie, not specifically in the context of weight management interventions), has identified several common barriers to engaging in PA among adults with overweight or obesity. These include lack of time[14,15]; physical barriers such as physical discomfort, poor fitness, or the possibility of injury[14-16]; psychological barriers such as low confidence, higher depressive symptoms, lack of motivation, and embarrassment[14]; and environmental barriers, such as limited access to public space, safety concerns, or financial constraints.[16] While these studies provide important insights into common types of barriers experienced by adults with higher body weights, individuals entering a BWL programme may have distinct experiences with PA, including with regard to barriers. For example, individuals seeking treatment may be more motivated to engage in PA than their non-treatment-seeking peers. On the other hand, the fact that these individuals are seeking structured intervention may indicate greater prior difficulty overcoming barriers to lifestyle change on their own. The documented higher mean body mass index (BMI), prevalence of certain medical comorbidities, and rates of depression among treatment-seeking adults with obesity relative to their non-treatment-seeking peers may also present unique barriers to PA.[17-19]

A limited number of studies have examined barriers to PA specifically in the context of structured BWL programmes. Additional research is needed to understand whether barriers to PA change over the course of BWL treatment and relate to measured PA. BWL programmes may influence participants' perceived PA barriers in either positive or negative directions. For example, BWL programmes may help to combat barriers by offering information about various types of low-impact activities that participants can try, providing supportive accountability, and helping to problem solve barriers as they arise.[20] Alternatively, given that individuals engaged in BWL are asked to spend substantial time on weight control activities (eg, meal planning), time may become an even greater barrier to PA during treatment, and motivation for PA may wane because of behavioural fatigue.[21] In partial support of these latter possibilities, one study found that clinicians perceived an increase in PA barriers among participants *after* initial weight loss.[22] However, this study did not assess participants' perceptions of PA barriers, which may differ from those of clinicians, and which are crucial for developing treatments that are acceptable and effective.[23] A workplace weight loss study asked participants to report on their barriers to PA, with results indicating that accessibility, interest, and time barriers were related to measured PA.[24] A feasibility study of a mobile-based diabetes prevention programme found that participants' perceived PA barriers decreased at 5 months in the intervention group but not in the control group.[25] However, because these two interventions differed from standard BWL treatment in key ways (eg, were individual vs group-based and had only approximately monthly in-person contacts), it is unclear if these findings generalize to more intensive, group-based BWL programmes and their participants. To our knowledge, only one study has assessed participants' perceptions of PA barriers over time and their relation to PA in the context of a standard BWL programme, finding that perceived PA barriers decreased significantly over a 6-month intervention and that, at 6 months, individuals who achieved ≥150 min/wk^{-1} of self-reported MVPA reported fewer PA barriers.[26] Further clarification of how participants' reported barriers change both during and after treatment and relate to measured MVPA in BWL programmes can inform intervention development efforts to better target perceived barriers at the times when they may be most likely to impede PA.

Lastly, prior research suggests that PA barriers may differ across gender, race, education, and BMI categories, although results have been mixed.[22,24] For example, in the previously described workplace weight loss study, white participants endorsed lack of interest, lack of motivation, and time constraints as barriers more frequently than did participants of other races,[24] whereas in the study of clinician-rated barriers, most weight loss barriers were related to being non-white.[22] Clinician-rated PA barriers were also related to being female vs male and having obesity vs overweight.[22] Identifying which participants are likely to be affected by certain PA barriers and how these barriers relate to measured MVPA could make it easier to identify those in need of tailored interventions quickly (ie, at treatment onset).

The current study sought to address these gaps in the literature by examining participants' perceived barriers to PA in a sample of adults with overweight and obesity participating in a 12-month BWL programme. Aim 1 was to characterize perceived barriers to PA in a BWL programme. Aim 2 was to examine changes in perceived PA barriers from baseline to 6 (midtreatment), 6 to 12 (end of treatment), 12 to 18 (6-mo follow-up), and 18 to 24 months (12-mo follow-up). It was hypothesized that PA barriers would decrease during treatment but likely experience a rebound after treatment ended. Aim 3 was to determine whether perceived barriers to PA were related to measured

MVPA at baseline, with the hypothesis that a negative association would be observed. Aim 4 was to examine whether changes in perceived barriers to PA were associated with measured MVPA during and after treatment, with the hypothesis that decreases in PA barriers would be associated with greater MVPA. Aim 5 was to identify associations between perceived barriers to PA and participant characteristics (ie, demographic factors and BMI); these analyses were exploratory (ie, no hypotheses identified) because of limited data or theory available.

2 | METHOD

2.1 | Participants and procedure

The present study is a secondary analysis of a randomized controlled trial comparing BWL interventions.[27] The parent study enrolled 283 participants. Eligibility criteria for the parent study included the following: age 18 to 70 years, BMI between 27 and 45 kg m^{-2}, and ability to engage in PA (ie, able to walk at least one city block without assistance). Individuals were deemed ineligible for the parent study if they had lost ≥5% of their body weight within the last 6 months, were taking medications with known impact on body weight, had a medical or psychiatric condition (eg, psychosis) that might impact participation in treatment, or were lactating, pregnant, or planning to become pregnant during the course of the study. All participants who participated in the parent study were included in the present study. The sample was primarily female (78.8%, n = 223) and white (65.7%, n = 186), with an average age of 53.22 years (SD = 9.65) and an average baseline BMI of 35.19 kg m^{-2} (SD = 4.98). Participants completed in-person research assessments at baseline (0 mo), 6 months (the end of the active weight loss phase), 12 months (the end of the weight loss maintenance phase), 18 months (follow-up 6 mo after treatment ended), and 24 months (follow-up 12 mo after treatment ended).

As part of the parent study, participants were randomly assigned to one of three BWL conditions. In all conditions, groups of 10 to 15 participants received twenty-six 75-minute sessions over a 12-month period. All conditions consisted of 6 months of BWL treatment intended to induce a weight loss of approximately 10%, followed by 6 months of weight loss maintenance treatment. All conditions taught core BWL skills (eg, self-monitoring and calorie reduction) modelled after the Diabetes Prevention Program[4] and the Look AHEAD manual.[3] However, conditions varied by the skills that were emphasized, with one condition providing standard behavioural treatment, one emphasizing changing the home food and exercise environment, and one emphasizing changing the home food and exercise environment using an acceptance-based framework (see Butryn et al[27] for details). Notably, all conditions assigned the same exercise prescription, which gradually increased by 10 min/wk^{-1} to a prescription of 250 min/wk^{-1} of MVPA performed in 10-minute bouts, with the recommended activity being brisk walking. As previously reported, weight loss outcomes did not differ by condition,[27] nor did minutes of bouted MVPA achieved. Preliminary analyses additionally found that total perceived PA barriers did not differ by condition at any time point (baseline: $F_{2,274}$ = .22, P = .81; 6 mo: $F_{2,238}$ = 2.47, P = .09; 12 mo: $F_{2,210}$ = .96, P = .38; 18 mo: $F_{2,201}$ = 1.35, P = .26; 24 mo: $F_{2,205}$ = 1.59, P = .21). As such, conditions were collapsed for the present analyses. The study was approved by an institutional review board. All participants provided written informed consent prior to participation.

2.2 | Measures

2.2.1 | Height and weight

Height and weight were measured in-person with participants in light street clothing by research staff using a Seca® scale (sensitive to 0.1 kg) and built-in stadiometer (rounded to the nearest 0.25″). Height was assessed at baseline. For this study, baseline height and weight were utilized to calculate baseline BMI.

2.2.2 | Physical activity

Participants were instructed to wear waist-worn Actigraph GT3X+ accelerometers for all waking hours for seven consecutive days at each assessment point. Consistent with prior research, a wear-day was considered valid if it consisted of at least 10 hours of wear-time; three wear days comprised a valid assessment.[28] MVPA was defined based on guidelines used in prior research.[29] A bout of MVPA was identified as a period of at least 10 minutes of at least moderate activity (with 2 min of drop time).[29]

2.2.3 | Demographics

Participants reported their age, gender, and race at baseline.

2.2.4 | Barriers to being active scale

At each time point, participants completed the Barriers to Being Active Quiz,[30] a 21-item scale that assesses seven barriers to PA (lack of time, social influence, lack of energy, lack of willpower, fear of injury, lack of skill, and lack of resources). Each barrier is assessed via three items, each on a 0 to 3 scale, with possible scores for individual barriers ranging from 0 to 9. The total score, indicating total barriers experienced by the participant, is a sum of each individual barrier score (possible range: 0 to 63). Higher scores indicate greater barriers to PA. Barriers that score 5 or more points are considered significant.[30]

2.3 | Statistical analysis plan

Analyses were conducted in SPSS v. 24[31] and RStudio.[32] Alpha levels were set at the .05 level. Total PA barriers (ie, the sum of the seven individual barriers) was the primary variable of interest; however, given the limited data on perceived PA barriers in the context of BWL treatment, analyses also explored the number of significant PA barriers (ie, the number of the seven barriers that a participant rated ≥5) and scores on the seven individual PA barriers. Descriptive data, including percentages, means, and standard deviations, were examined for all demographic characteristics, perceived barriers, and MVPA. Given the small proportion of individuals identifying as races other than white or African American, analyses examining race only included those identifying as one of these two racial categories; other participants were excluded from these analyses (but were included in all other analyses).

Missing data on demographics and PA barriers were not imputed because of the nature of these measures (ie, concerns that imputing these types of variables would bias results); thus, participants with missing data from these measures were not included in analyses. Participants with missing data did not differ from those with complete data on baseline BMI (subset with missing data: M = 35.83 kg m^{-2}, SD = 4.91, subset with complete data: M = 34.71 kg m^{-2}, SD = 4.99, t_{275} = −1.97, P = .06), baseline bouted MVPA (subset with missing data: M = 55.42 min/wk^{-1}, SD = 105.33, subset with complete data: M = 44.53 min/wk^{-1} SD = 71.26, $t_{180.43}$ = −.94, P = .35), baseline total PA barriers (subset with missing data: M = 19.73, SD = 11.16, subset with complete data: M = 20.55, SD = 9.89, t_{275} = .65, P = .52), or gender (subset with missing data: 23.4% male, 76.6% female, subset with complete data: 19.5% male, 80.5% female, X^2(1, N = 283) = .63, P = .47). However, African American participants comprised a higher proportion of those with missing data (38.3% African American and 61.7% white) than did those with complete data (25.3% African American and 74.7% white), X^2(1, N = 269) = 5.16, P = .02, and those with missing data were significantly younger (M = 51.83 years, SD = 10.39) than those with complete data (M = 54.29 years, SD = 8.93), $t_{238.48}$ = 2.09, P = .04.

To examine aim 1 (characterizing barriers to PA in the context of BWL), descriptive statistics were examined. For aim 2 (change in perceived PA barriers over time), repeated-measures analyses of variance (ANOVAs) were conducted with the following assessment points included: months 0, 6, 12, 18, and 24; polynomial contrasts were examined given that a quadratic relationship between time and perceived barriers was hypothesized. For aim 3 (examining relationships between perceived barriers to PA and measured MVPA at baseline), Pearson correlations were computed among baseline perceived PA barriers and baseline bouted MVPA (note: given research that BMI predicts lower activity levels,[33] baseline BMI was considered as a covariate in these relationships, but because it was not significantly associated with baseline MVPA in this sample, it was not included). For aim 4, to examine relationships between change in perceived PA barriers and MVPA, ordinary least squares (OLS) regression analyses were examined controlling for baseline bouted MVPA, which predicted bouted MVPA at subsequent time points. For aim 5 (associations between perceived PA barriers and participant characteristics), one-way ANOVAs were conducted to identify differences in PA barriers by categorical demographic factors (African American vs white, male vs female), and Pearson bivariate correlations were conducted to assess relationships between continuous demographic variables (age and BMI) and PA barriers.

3 | RESULTS

3.1 | Characterizing barriers to PA

Descriptive statistics (means and standard deviations) for total perceived PA barriers, number of significant PA barriers, and each of the individual PA barriers at each time point are presented in Table 1 . Correlations among baseline perceived PA barriers (as well as baseline BMI, see aim 3) are depicted in Table 2. Notably, most individual perceived PA barriers were correlated with one another and with total PA barriers and number of significant PA barriers.

3.2 | Change in PA barriers during and after treatment

Results from repeated-measures ANOVAs testing for a quadratic effect of time on perceived PA barriers (as well as bouted MVPA, for reference) are presented in Table 1. As hypothesized, a significant quadratic effect of time on total PA barriers was observed, as depicted in Figure 1, $F_{1,158}$ = 43.95, P < .001. Post hoc pairwise comparisons revealed that total PA barriers decreased significantly (P < .001) from baseline (M = 20.55, SD = 9.89) to 6 months (ie, midtreatment: M = 14.32, SD = 11.61), did not change significantly (P = .84) from 6 to 12 months (ie, by end of treatment: M = 14.48, SD = 11.52), increased significantly (P = .008) between end of treatment and 18-month follow-up (M = 16.33, SD = 11.91), and did not change significantly (P = .79) between 18-month follow-up and 24-month follow-up (M = 16.52, SD = 11.22). Of note, perceived PA barriers remained significantly below baseline levels at all time points, despite increases after treatment ended. Number of significant PA barriers (ie, barriers scoring ≥ 5; also depicted in Figure 1) followed a similar pattern, with a significant quadratic effect observed, $F_{1,158}$ = 41.31, P < .001, such that number of significant barriers decreased significantly by midtreatment but began to increase by follow-up, returning to near-baseline levels by 24 months. Social influence and lack of willpower followed a similar trend to total PA barriers. Lack of time, energy, and resources decreased by midtreatment and remained below baseline by end of treatment (P's < .001) but increased to near-baseline levels by follow-up. Lack of skill was only below baseline at end of treatment (P < .001), and fear of injury did not change over time.

3.3 | Baseline PA barriers and MVPA

At baseline, all perceived PA barriers except fear of injury were associated with lower amounts of MVPA, (P's < .05). These results are presented in Table 2.

3.4 | Change in PA barriers and MVPA

Greater decreases in perceived PA barriers from baseline to 6 (midtreatment), 12 (end of treatment), and 24 months (12-mo

TABLE 1 Participants' perceived PA barriers over time

	Baseline (Pre-Tx)	6 mo (Mid-Tx)	12 mo (End of Tx)	18 mo (Follow-up)	24 mo (Follow-up)	Omnibus ANOVA for Quadratic Term	Post Hoc Pairwise Comparisons Between Time Points
	M (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)		
	n = 277	n = 241	n = 213	n = 204	n = 208		
Total barriers	20.20 (10.44)	15.64 (12.06)	14.44 (11.37)	16.74 (11.87)	17.55 (11.74)	$F_{1,158}$ = 43.95 P < .001	6, 12, 18, 24 < BL 18, 24 > 6, 12
Number of significant barriers	1.86 (1.60)	1.29 (1.73)	1.17 (1.58)	1.48 (1.65)	1.65 (1.71)	$F_{1,158}$ = 26.30 P < .001	6, 12, 18 < BL 24 > 12
Lack of time	3.47 (2.59)	2.92 (2.48)	2.67 (2.57)	3.16 (2.59)	3.22 (2.74)	$F_{1,153}$ = 13.38 P < .001	6, 12 < BL
Social influence	3.01 (2.10)	2.34 (2.08)	2.21 (1.95)	2.60 (2.18)	2.38 (2.01)	$F_{1,153}$ = 9.79 P = .002	6, 12, 24 < BL
Lack of energy	3.69 (2.44)	3.00 (2.49)	2.63 (2.31)	3.04 (2.50)	3.35 (2.65)	$F_{1,147}$ = 29.40 P < .001	6, 12, 18 < BL 24 > 12
Lack of willpower	5.34 (2.84)	3.32 (2.95)	3.20 (2.99)	3.94 (3.19)	4.20 (2.94)	$F_{1,153}$ = 79.82 P < .001	6, 12, 18, 24 < BL 18, 24 > 6, 12
Fear of injury	1.26 (1.77)	1.12 (1.84)	1.00 (1.59)	1.11 (1.66)	1.26 (1.88)	$F_{1,155}$ = 2.61 P = .11	N/A
Lack of skill	1.56 (1.93)	1.16 (1.81)	1.23 (1.84)	1.32 (1.96)	1.48 (1.94)	$F_{1,145}$ = 4.63 P = .03	6 < BL
Lack of resources	1.98 (1.63)	1.63 (1.97)	1.38 (1.74)	1.56 (1.84)	1.68 (1.90)	$F_{1,147}$ = 5.88 P = .02	12 < BL
Bouted MVPA (min/wk^{-1})	49.09 (87.14)	98.08 (107.89)	89.41 (108.51)	71.75 (96.34)	61.75 (96.26)	$F_{1,148}$ = 32.14 P < .001	6, 12, 18 > BL 6 > 12, 18

Note. Individual barriers to PA are each assessed on a 0- to 9-point scale (total barriers: 0- to 63-point scale) with higher scores indicating greater barriers, using the Barriers to Being Active Scale.[30] Barriers rated as ≥5 are considered significant barriers.

BL, baseline; MVPA, moderate-to-vigorous physical activity; Tx, treatment.

TABLE 2 Pearson correlations among participants' perceived PA barriers and MVPA at baseline

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. MVPA	–	−.28**	−.23**	−.19**	−.20**	−.17**	−.35**	−.07	−.13*	−.14*
2. Total barriers		–	.89**	.72**	.73**	.75**	.72**	.47**	.62**	.57**
3. Number of significant barriers			–	.70**	.67**	.70**	.66*	.34**	.51**	.49**
4. Lack of time				–	.43**	.67**	.49**	.13*	.21**	.27**
5. Social influence					–	.49**	.55**	.21**	.35**	.33**
6. Lack of energy						–	.47**	.15*	.25**	.29**
7. Lack of willpower							–	.11	.29**	.18**
8. Fear of injury								–	.55**	.32**
9. Lack of skill									–	.42**
10. Lack of resources										–

Abbreviation: MVPA, moderate-to-vigorous physical activity.

*P < .05.

**P < .005.

follow-up) were associated with greater MVPA at 6, 12, and 24 months, respectively, controlling for baseline MVPA (6 mo: $F_{2,201}$ = 19.33, P < .001, B = 1.90, t_{201} = 2.95, P = .004; 12 mo: $F_{2,150}$ = 24.75, P < .001, B = 2.61, t_{150} = 3.60, $P \leq$ .001; 24 mo: $F_{2,150}$ = 4.46, P = .01, B = 2.04, t_{150} = 2.72, P = .007). Change in perceived barriers from baseline to 18 months (6-mo follow-up), controlling for baseline MVPA, was not significantly related to 18-month MVPA, $F_{2,172}$ = 18.90, P < .001, B = 0.91, t_{172} = 1.50, P = .14.

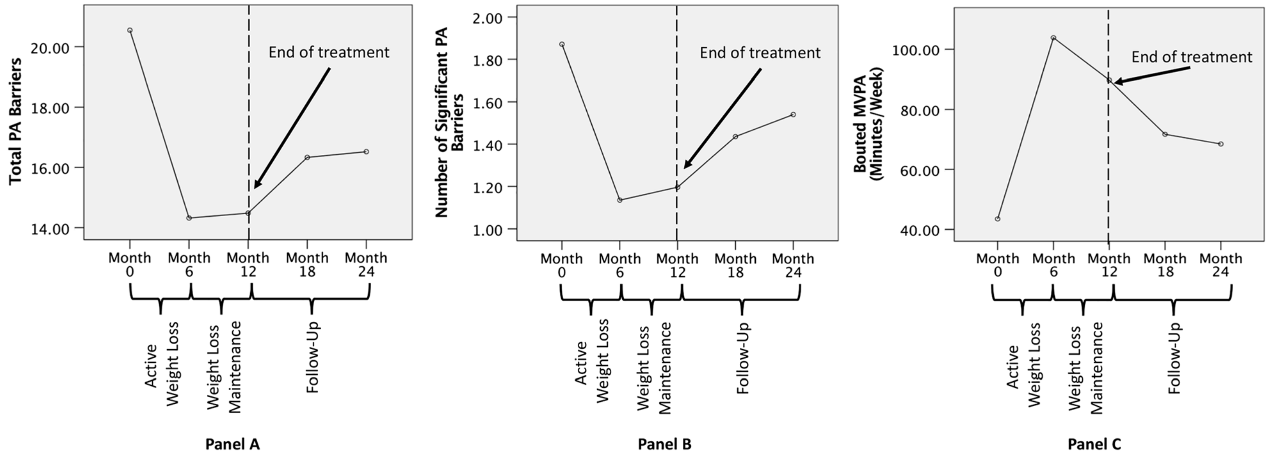

FIGURE 1 A, Total barriers (sum of the seven barriers) decreased significantly during the active weight loss phase and remained significantly below baseline during the weight loss maintenance phase but returned to near-baseline levels in the follow-up phase. B, Number of significant barriers decreased significantly during the active weight loss phase and remained below baseline during weight loss maintenance and the first 6 mo of follow-up (12-18 mo), but not the final 6 mo of follow-up (18-24 mo). C, Minutes per week of bouted moderate-to-vigorous physical activity (MVPA) followed an opposite pattern to PA barriers, increasing during active treatment and decreasing in the follow-up phase

3.5 | PA barriers and demographic variables

3.5.1 | Race

At baseline, white participants (*M* = 21.18, SD = 10.54) reported greater total PA barriers than did black participants (*M* = 17.48, SD = 10.04), $F_{1,261}$ = 6.97, *P* = .009. Exploratory analyses found that white participants (*M* = 1.97, SD = 1.62) also reported a greater number of significant PA barriers than did black participants (*M* = 1.47, SD = 1.44), $F_{1,261}$ = 5.69, *P* = .02. Examination of the individual barriers revealed that, compared with black participants, white participants reported lack of time ($F_{1,168.67}$ = 11.29, *P* = .001), social influence ($F_{1,260}$ = 12.26, *P* = .001), and lack of willpower ($F_{1,258}$ = 12.31, *P* = .001) as greater barriers. There were no differences by race on lack of energy ($F_{1,259}$ = 1.75, *P* = .19), fear of injury ($F_{1,258}$ = 0.21, *P* = .65), lack of skill ($F_{1,298}$ = 1.08, *P* = .30), or lack of resources ($F_{1,258}$ = 3.70, *P* = .06).

3.5.2 | Gender

There were no differences in by gender on total PA barriers ($F_{1,275}$ = 0.03, *P* = .87), number of significant PA barriers ($F_{1,275}$ = 0.28, *P* = .60), or any of the seven individual PA barriers.

3.5.3 | Age

Younger age was associated with greater total PA barriers (*r*(275) = −.14, *P* = .02) and greater number of significant PA barriers (*r*(275) = −.16, *P* = .01). Specifically, scores on the lack of time (*r*(272) = −.16, *P* = .01), energy (*r*(272) = −.23, *P* < .001), and resources (*r*(272) = −.15, *P* = .01) were higher for younger participants. There were no differences by age on willpower (*r*(272) = .01, *P* = .93), social influences (*r*(273) = −.03, *P* = .59), fear of injury (*r*(272) = .02, *P* = .70), or lack of skills (*r*(272) = .03, *P* = .68).

3.5.4 | Body mass index

At baseline, BMI was not associated with total barriers (*r*(271) = .04, *P* = .47), number of significant barriers (*r*(271) = .07, *P* = .255), or any of the seven individual barriers.

4 | DISCUSSION

This study sought to examine participants' perceived barriers to engaging in PA during and after a BWL programme. Despite the well-known benefits of PA for weight control and general health,[6,34] few adults enrolled in BWL programmes adhere to PA prescriptions, making it crucial to identify barriers to doing so.[12,13] Thus, within the context of a BWL programme, this study aimed to (a) characterize perceived barriers to PA; (b) examine how perceived PA barriers change by midtreatment, end of treatment, 6-month follow-up, and 12-month follow-up; (c) investigate relationships between perceived PA barriers and measured MVPA at baseline; (d) assess the relationship between changes in perceived PA barriers and measured MVPA during and after treatment; and (e) identify associations between perceived PA barriers and demographic characteristics.

Both total perceived barriers to PA and number of significant PA barriers decreased significantly during the first 6 months of BWL treatment, consistent with one prior study that examined participants' perceptions of PA barriers during a 6-month BWL programme.[26] However, in the present study, which is the first to our knowledge to examine how perceived PA barriers change during the follow-up period of a BWL programme, PA barriers began to increase again after treatment ended. Total PA barriers remained below baseline levels at all time points, including 24-month follow-up, which is notable because it suggests that participants continued to benefit from intervention effects for up to a year after treatment ended. However, number of significant PA barriers had returned to near-baseline levels by

24 months, as had several individual barriers (lack of time, energy, resources, and skill). The only individual barriers that remained significantly below baseline at 24-month follow-up were lack of willpower and social influence. These results suggest that a standard BWL programme addresses many perceived PA barriers during active treatment, likely because of skills like problem solving and goal setting; however, once treatment is removed, many barriers appear to return. These results are perhaps unsurprising given that they mirror patterns of weight and PA outcomes typically observed in BWL treatment: During active treatment, participants on average experience clinically meaningful weight losses and increases in PA, but these treatment gains are typically not maintained after treatment ends.[35] Thus, these results highlight the importance of identifying interventions that provide specific skills to help maintain improvements in PA barriers once BWL ends. For example, it may be helpful to regularly assess PA barriers during treatment, help participants develop an awareness of how their particular barriers have changed, and create a plan for maintaining positive changes after formal intervention concludes.

It is also important to note that, while perceived barriers decreased significantly, the magnitude of the decrease was relatively small. This small magnitude may be driven by the fact that mean ratings on each barrier were relatively low at the beginning of treatment, such that that there was not much room for large decreases. Participants in this sample may have entered treatment with moderate barriers to PA or may have underreported barriers at the start of treatment because of demand characteristics. Alternatively, the Barriers to Being Active Quiz may yield scores that appear lower than expected (eg, few mean scores in the "significant" range of ≥5) but are actually meaningful in this population. In support of this possibility, the present study replicated the pattern observed in a prior study of adults with overweight or obesity that used the Barriers to Being Active Quiz and found that, at baseline, the only individual barrier that was, on average, rated as significant was lack of willpower.[25]

Nonetheless, the fact that barriers were related to measured MVPA suggests that, even if participants reported relatively low barriers to PA, these barriers were still meaningful indicators of treatment processes. Indeed, participants who entered treatment with greater PA barriers also had lower levels of baseline MVPA. Given the cross-sectional nature of this comparison, it is unclear whether low levels of baseline MVPA contributed to greater perceived PA barriers (ie, individuals who engage in less PA at baseline may perceive more barriers simply because they have not attempted to engage in PA yet), or if greater perceived PA barriers contributed to lower levels of MVPA, or if the relationship is bi-directional. Interestingly, the only other study to our knowledge to examine perceived PA barriers during standard BWL did not find a relationship between perceived PA barriers and PA at baseline, possibly because of measurement differences (ie, a different measure of perceived PA barriers and use of self-reported versus accelerometer-measured PA).[26] Participants who experienced larger decreases in PA barriers also engaged in greater levels of MVPA at midtreatment, end of treatment, and 24-month follow-up, suggesting that decreases in PA barriers contribute to increases in MVPA. It should be noted that the measure used in this study assessed participants' *perceptions* of their PA barriers, which may capture subjective beliefs about PA barriers more so than objective barriers. For example, two participants may have similar time constraints, but one may perceive lack of a time as a more significant barrier than the other. Although it also would be useful to measure objective barriers to PA (including environmental and neighbourhood level barriers), this study suggests that participants' perceptions of PA barriers are meaningful indicators of PA behaviour that clinicians may want to consider assessing and addressing during the course of treatment.

Within this BWL sample, some perceived PA barriers differed by age and race, suggesting that there may be subtypes of participants that present with differing barriers and therefore may have different treatment needs. Alternatively, these results could suggest that certain subgroups of participants are less likely to report barriers to PA, perhaps because they are less aware of them or because they experience social pressure to underreport. White participants reported greater perceived PA barriers and a greater number of significant PA barriers than did black participants. Additionally, they rated willpower, lack of time, and social influences as greater barriers than did black participants; there were no differences in the opposite direction. These findings are inconsistent with those from a prior study that found that the majority of clinician-rated weight control barriers during a BWL programme were associated with being non-white.[22] This difference in findings might highlight that clinicians and participants tend to hold differing perceptions of a participant's weight control barriers, as documented in prior research.[36] It is also possible that the measure used in this study was better able to capture the barriers typically faced by white participants than by black participants. Prior research has demonstrated that black participants have several culturally specific barriers to PA (eg, hair care maintenance) that are often not captured during assessments or addressed in treatments.[37]

Younger participants reported greater total barriers and number of significant barriers than did older participants. Specifically, younger participants rated lack of time, energy, and resources as greater barriers to PA than did older participants. Because this sample was middle-aged on average, the youngest quartile for age was 47 years and younger, whereas the highest quartile was 60 years and older. Younger participants in this sample (ie, individuals who are roughly in their 40s) may have a greater number of competing responsibilities (including work and caring for a family) that may make time, energy, and resources more limited.[38] Older participants in this sample are roughly at the average age for retirement[39] and may therefore have fewer work and caretaking obligations at this juncture in their lives, making it easier to devote time, energy, and resources towards weight control (and PA in particular).

Perceived PA barriers were unrelated to gender or baseline BMI in this sample, which contradicts findings from the study of clinicians' perceptions of participant barriers, which suggested that women and those with higher BMIs may have greater barriers to PA.[22] Again, this finding may highlight differences in how clinicians versus participants view barriers. Additionally, it is possible that the smaller proportion of males in this study (21.2%) and the constrained BMI range because of eligibility criteria impacted the ability to detect significant effects.

The study of clinicians' perceptions of participant barriers (drawn from the lifestyle modification arm of the Diabetes Prevention Program) included a slightly higher proportion of males (32.0%), and eligibility criteria allowed for a wider BMI range at enrolment (≥24 vs 27-45 kg m^{-2} in the present study).[22,40]

This study had several strengths, including a relatively large sample size of adults engaged in BWL, assessment of barriers to PA at multiple time points, and measurement of MVPA using accelerometers (as opposed to self-report). However, there were also limitations that should be noted. This study was a secondary analysis that collapsed data from three different BWL conditions. Although no differences across conditions were observed in weight, MVPA, and perceived PA barriers, each intervention taught participants to manage barriers somewhat differently, which may limit the generalizability of these results. Additionally, the Barriers to Being Active Quiz,[30] which was used to examine perceived PA barriers in this study, has not been well-validated and may miss crucial barriers for certain subgroups of participants. Future research should utilize other measures to determine if the findings from this study hold. It may be particularly useful to assess both perceived and objective PA barriers (eg, neighbourhood/environment characteristics, such as access to safe spaces to walk, and other social determinants of health) within the same study to determine how these factors each contribute to PA. Another limitation of the current study is that the sample was relatively homogenous on certain dimensions, including gender (primarily female), race (primarily white), and age (primarily middle-aged), which may affect generalizability of results and, more specifically, may have made it difficult to observe certain demographic differences in PA barriers. Finally, individuals who did not complete measures were dropped from analyses, which may have impacted findings at follow-up time points when attrition was the highest. Participants with missing data were younger, and a higher percentage were African American than were those with complete data, which limits the ability to generalize some results to those demographic groups. These demographic differences are consistent with prior studies finding that participants who are younger and/or African American are more likely to drop out of BWL trials and underscore the need for future research to determine how best to engage these individuals.[41,42]

Overall, it appears that participants' perceptions of PA barriers change over the course of BWL, are associated with measured MVPA levels, and vary by demographic group. Interventionists may want to measure PA barriers in their participants throughout treatment and keep in mind that certain participants (eg, younger participants) may present with greater barriers at treatment onset. Future research should attempt to identify interventions that help to promote long-term reductions in PA barriers after treatment ends.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest to disclose.

AUTHOR CONTRIBUTIONS

M.L.B. conceived the study, M.L.B. and S.G.K. carried out study procedures, C.C.C. and S.R.R. conducted the literature search, C.C.C. conducted data analyses, and all authors were involved in data interpretation and writing the paper and had final approval of the submitted version.

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