Lifestyle interventions (LIs) can treat metabolic syndrome and reduce the incidence of type 2 diabetes mellitus (T2DM) in high-risk individuals. However, realising the health benefits of LIs in routine clinical practice remains elusive. In January 2010, an LI model was created in a rural primary care practice and spread to four other rural communities. We present changes in health indicators among participants in two physician-led interventions.

Methods
Ethics approval was obtained from the Northern Health Authority and the University of British Columbia (Ref. no. H10-02573), Canada. The intervention was open to both individuals wanting to lose weight and those interested in a non-pharmacological approach to managing insulin resistance. The foundation of the intervention model was group medical visits, with 15 - 25 participants overseen by a clinical facilitator. The clinically facilitated meetings featured a presentation germane to living a healthier lifestyle, such as sugar addiction, medication management, maintaining adherence while on vacation, etc. The remainder of the meeting time was used to answer participants' questions and address experiences relating to living a healthier lifestyle. At the first site (S1), programme length was determined by participants’ progress towards their health goals. At the second site (S2), the intervention was 3 months in length. Individuals requiring additional support were encouraged to form peer-led support groups on their own initiative.

A quality improvement process whereby various lifestyle prescriptions were tested with different groups was used to refine the intervention at S1. Results from these non-randomised ‘trials’ were tracked using local electronic medical record data. The outcome of this process was an intervention featuring a two-stage diet programme. The weight-loss diet restricted calories to approximately 1 100 and 1 500 kcal/day for women and men, respectively; participants were instructed to avoid foods containing sugar and other refined carbohydrates, in addition to restricting the consumption of dietary fat. To assist in appetite control, participants were instructed not to undertake moderate or vigorous physical activity until they had reached their weight-loss goal. After reaching their target weight, a high-fat diet was used for weight maintenance. The use of a high-fat diet was predicated on the high prevalence of insulin resistance in the patient population and favourable changes in multiple health indicators in randomised trials of up to 2 years’ duration in such populations. Foods consumed on the maintenance diet included beef, poultry, fish, eggs, oils, moderate amounts of hard cheeses, and small amounts of nuts, nut butters, seeds and berries.

Measurements
Height was measured using a stadiometer, with participants wearing no shoes. Waist circumference was measured with a flexible tape measure and with the help of another participant. Weight was measured at every group visit with participants wearing light indoor clothing. Participants completed the PHQ-9 questionnaires to assess their mood. Scores on the PHQ-9 range from 0 (absence of depressive symptoms) to 27 (severe depressive symptoms). A score of ≥10 on the PHQ-9 was used to indicate depression.

Evaluation rationale, data extraction and statistical analyses
Following the success of the intervention at S1, the intervention model spread to four other rural communities. The intervention was created in 2010 by a physician (SDT) working in a service contract environment and was adopted into the practices of four fee-for-service physicians, a nurse practitioner and two registered nurses. The initial evaluation was planned to document health changes at S1, but owing to the unanticipated spread of the intervention, weight-loss results were included in the evaluation from four fee-for-service physicians.
The clinical and community observations from the other sites, which have not been formally evaluated, were consistent with the health improvements reported here.

Data were extracted from an electronic medical system during the most active periods of the interventions; this was early 2010 to 2011 for S1, while for S2 anthropometric data were retrieved beginning in early 2012. For S1, where cardiometabolic data were available, baseline data were sought no earlier than January 2008. The time between the first and last weighing was used to define the time spent in the LIs by participants at S1, as participants were weighed at each meeting. Intensity of participation in the LI was calculated by dividing the months in the programme by the number of visits. We used International Diabetes Federation criteria to classify participants as having metabolic syndrome (MetS). A haemoglobin A1c (HbA1c) measurement was used to indicate the presence of diabetes, in accordance with local clinical protocols.

Differences between anthropometric and biochemical variables were calculated, and paired t-tests were used to assess whether baseline values were statistically different to those at follow-up. Owing to the small sample size of individuals with HbA1c measurements (n=118), the Wilcoxon signed-rank test was used to test whether follow-up values were significantly different from baseline. We used multivariable analysis to examine the predictors of changes in body mass index (BMI) between baseline and follow-up in participants at S1. All statistical analyses were conducted on SAS version 9.2 (SAS Institute, USA).

**Results**

This study documented the creation and replication of a successful LI in rural British Columbia (BC). We evaluated health improvements among 372 participants at two physician-led interventions in a service contract (S1) and a fee-for-service practice context (S2); 139 participants were evaluated at S1 and 233 at S2, which began 2 years after the creation of the LI model at S1 (Tables 1 and 2). Participants at both sites were mainly women (~80%), with a mean age of S2 (standard deviation (SD) 13) years and S1 (SD 14) years for S1 and S2, respectively. Participants ranged in age from 16 to 85 years. Additional measures were available from participants at S1, including cardiometabolic indicators (n=119) and mood scores (n=111). More than 90% of participants had a high waist circumference, while the average baseline BMI was 37 kg/m². Consistent with the high prevalence of obesity, 57.6% (80/139) of participants began the intervention at S1 with MetS while 12.9% (18/139) had T2DM.

Participants in these LIs had unusually large improvements in health, particularly given the real-world contexts of the interventions. For example, 372 participants had weight loss of >12% (Fig. 1), while in the Diabetes Prevention Program, a well-resourced trial, the weight-loss goal was 7% of initial body weight. Among other studies examining LIs in routine practice, average weight loss was 3 - 5% at year 1.[1] Consistent with the considerable weight loss, participants at S1 showed marked improvements in their cardiometabolic profile. For example, blood triglyceride concentrations, measured among 119 participants at S1, decreased by 34%, probably a reflection of the reduced intake of starches and sugars.[3] Among the 18 individuals with T2DM in the LI at S1, there was a mean decrease in HbA1c of 0.5%, a figure that fails to account for any reductions in pharmacotherapy, which were not documented in this report. The extent of the changes in cardiometabolic indicators that were measured in this study are therefore a conservative estimate of the health improvements, as participants experienced reductions in the use of

**Table 1. Characteristics at baseline and follow-up of participants at S1 in a service contract primary care practice in rural BC, Canada (N=139)**

| Characteristic | Baseline | Follow-up | Change | p-value |
|---------------|----------|-----------|--------|---------|
| Age (years), mean (SD) | 52.4 (13.1) | - | - | - |
| Sex, % female | 80.4 | - | - | - |
| Height (m), mean (SD) | 1.7 (0.1) | - | - | - |
| Weight (kg), mean (SD) | 97.2 (22.6) | 84.2 (20.6) | -12.8 (8.9) | <0.0001 |
| BMI (kg/m²), mean (SD) | 35.4 (7.0) | 30.7 (6.4) | -4.7 (3.2) | <0.0001 |
| % with elevated waist circumference | 90.7 | 66.2 | -24.5 | <0.0001 |
| % with metabolic syndrome | 57.6 | 19.4 | -38.2 | <0.0001 |
| % with PHQ-9 score ≥10 | 23.7 | 7.9 | -15.8 | <0.0001 |
| PHQ-9 score (n=111), mean (SD) | 7.0 (5.2) | 3.4 (4.6) | -3.6 (4.6) | <0.0001 |
| Blood pressure (mmHg, n=119), mean (SD) | 136.6/85.4 | 122.5/77.0 | -14.1/8.4 | <0.0001 |
| HDL-C (mmol/L, n=119), mean (SD) | 1.34 (0.35) | 1.42 (0.35) | 0.08 (0.27) | 0.0019 |
| LDL-C (mmol/L, n=119), mean (SD) | 3.31 (1.04) | 2.90 (0.88) | -0.41 (0.97) | <0.0001 |
| Triglyceride concentration (mmol/L, n=119), mean (SD) | 1.63 (0.80) | 1.08 (0.59) | -0.56 (0.64) | <0.0001 |
| Triglyceride/HDL-C ratio, mean (SD) | 1.36 (0.91) | 0.84 (0.73) | -0.52 (0.77) | <0.0001 |
| Fasting blood glucose concentration (mmol/L, n=111), mean (SD) | 5.91 (1.74) | 5.32 (1.17) | -0.59 (1.47) | <0.0001 |
| HbA1c concentration (% n=18), mean (SD) | 7.47 (1.64) | 6.95 (1.09) | -0.52 (1.91) | 0.089 |

HDL-C = high-density lipoprotein cholesterol; LDL-C = low-density lipoprotein cholesterol.
insulin and oral hypoglycaemic, antihyper-
tensive and cholesterol-lowering agents. To
the intervention participants, the reductions
in pharmacotherapy were an empowering
’side-effect’ of the intervention, and for the
clinicians administering the intervention,
use of this therapeutic approach improved
control of hyperglycaemia, hypertension and
dyslipidaemias.

Similar to the findings of others,[5,6] we
documented improvements in mood among
participants in the intervention at S1 (n=111).
Among the 32 participants with mood
scores indicative of depression (PHQ-9 score
≥10), the mean decrease in score was 7.0
(SD 5.2). It was not possible to separate
the effect of participating in group sessions
from the physiological effects of the LI, as
these exposures are probably associ-
ated with improvements in mood. The mood
improvements associated with weight loss
may be attributable to reductions in patho-
physiological processes such as inflamma-
tion and hypothalamic-pituitary-adrenal axis
activation that are common to both insulin
resistance and mood disorders.[7]

We examined the predictors of weight
change among participants at S1 using
multivariable analysis (Table 3). We found
that each visit per month increase in the LI
was associated with a 0.7 kg/m² greater loss
in BMI after controlling for sex, age, baseline
BMI and time spent in the programme.

Conclusions

We documented the creation of an LI model
and the replication of this intervention in
different rural practices. This intervention
was a powerful wellness tool, empowering
not only patients[10] and physicians but the
rural communities, which can be burdened
with a high prevalence of chronic disease.

The intervention model documented in
this study differed from the consensus
prescription for LIs. For example, participants
in this intervention were counselled to
restrict moderate to vigorous physical
activity while on the weight-loss diet; in
contrast, in two highly cited randomised
trials, participants were encouraged to
undertake 150[11] and 175[11] minutes per week
of moderate physical activity, respectively.
More controversially, our intervention used
a high-fat diet for weight maintenance, while
in the Diabetes Prevention Program and the
Look AHEAD trials, participants were
counseled to avoid consuming foods rich in
dietary fat. These conflicting prescriptions
allude to a state of uncertainty that exists
with regard to the optimal prescription for
LIs for individuals with insulin resistance.
This situation persists despite decades-old
findings by Reaven (Garg et al.[12]) showing
that insulin resistance is fundamentally a
disorder of carbohydrate metabolism.

Given the magnitude of the obesity and
diabetes pandemics, there is a public health
 imperative to provide practitioners with evi-
 dence that supports effective interventions.
While well-resourced randomised trials are
powerful analytical tools, rigorous trials
take decades to yield results and are argu-
ably prohibitively expensive.[13] Moreover,
study results often lack generalisability to
routine practice.[14] In contrast, the quality
improvement process used in this study was
not only powerful, as evidenced by the replication
of the intervention model at four different
practice sites, but offers a more expeditious
way to spread effective interventions for
obesity and insulin resistance.

Despite the rigour of our quality improve-
ment process, our efforts to communicate
the merits of this intervention to health
system administrators met with a frustrating
lack of uptake. This is not surprising, given
that the research literature has many com-
 peting ‘solutions’ for the epidemics of obesity
and diabetes,[15] many of which are difficult
to falsify.[16] To support health administra-
tors in making evidence-based decisions, a
broader set of data sources could be used to
evaluate health system interventions such
as that documented here. For example, the
Institute of Health Improvement recom-
ends using indicators that measure patient
satisfaction, health system cost and popula-
tion health status,[17] complementing data
from physician records. A broader set of
health system indicators combined with lon-
ger-term follow-up of intervention partici-
pants would enable evidence-based health
system decision-making in a climate of fiscal
restraint.

Taken as a whole, our evidence suggests
that a timely response to the obesity and dia-
betes pandemics requires a critical rethink
not only of the current evidence base under-
pinning LIs, but also of the systems with
which evidence is generated and integrated
into health system practice.

Conflicts of interest. SDT, KN, DC, MM,
SVDS and JF have no conflicts of interest
to declare. SM is the founder of a sole
proprietorship. Approach Analytics, providing
analytical support to clinical and public health
initiatives. JW is on the Scientific Advisory

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**Table 2. Characteristics at baseline and follow-up of participants at S2 in a rural fee-
for-service primary care practice in BC, Canada (N=233)**

| Characteristic                          | Baseline | Follow-up | Change | p-value |
|----------------------------------------|----------|-----------|--------|---------|
| Age (years), mean (SD)                 | 51.3 (14.1) | - | - | - |
| Sex, % female                          | 81.6 | - | - | - |
| Height (m), mean (SD)                  | 1.6 (0.1) | - | - | - |
| Weight (kg), mean (SD)                 | 101.0 (21.4) | 89.5 (19.4) | -11.4 (6.4) | <0.0001 |
| BMI (kg/m²), mean (SD)                 | 37.2 (6.6) | 33.0 (6.2) | -4.3 (2.5) | <0.0001 |
| % with elevated waist circumference    | 98.3 | 83.3 | -15.0 | <0.0001 |

**Table 3. Predictors of change in BMI among participants in an LI in rural BC, Canada
(N=132)**

| Parameter                              | Change in BMI | Standard error | p-value | R² (full model = 0.23) |
|----------------------------------------|---------------|----------------|---------|------------------------|
| Sex (women referent)                   | −0.236        | 0.646          | 0.7151  | 0.000                  |
| Age of participants (years)            | 0.036         | 0.019          | 0.0618  | 0.024                  |
| Baseline BMI (kg)                      | 0.179         | 0.035          | <0.0001 | 0.151                  |
| Months in programme                    | 0.138         | 0.065          | 0.0347  | 0.018                  |
| No. of visits/month                    | 0.721         | 0.254          | 0.0045  | 0.033                  |
Board for Atkins Nutritionals Inc. and has accepted honoraria and travel expenses to attend meetings. TN is the author of the books Lore of Running and Waterlogged and co-author of The Real Meal Revolution, Raising Superheroes and Challenging Beliefs. All royalties from the sales of The Real Meal Revolution and Raising Superheroes and related activities are donated to the Noakes Foundation, of which he is the chairman and which funds research on insulin resistance, diabetes and nutrition as directed by its Board of Directors. Money from the sale of other books is donated to the Tim and Marilyn Noakes Sports Science Research Trust, which funds the salary of a senior researcher at the University of Cape Town, South Africa. The research focuses on the study of skeletal muscle in African mammals with some overlap to the study of type 2 diabetes in carnivorous mammals and of the effects of (scavenged) sugar consumption on free-living (wild) baboons.

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