Preventive Medicine 89 (2016) 15–22

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Home-based lifestyle intervention for rural adults improves metabolic syndrome parameters and cardiovascular risk factors: A randomised controlled trial

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ARTICLE INFO

Article history:
Received 19 January 2016
Received in revised form 3 May 2016
Accepted 15 May 2016
Available online 16 May 2016

Keywords:
Metabolic syndrome
Rural health
Chronic disease
Prevention
Health promotion

ABSTRACT

The presence of metabolic syndrome (MetS) increases the risk of developing type 2 diabetes and cardiovascular disease. Targeted interventions to reduce MetS for high risk populations are crucial for the prevention of these chronic diseases. This study evaluated the effectiveness of a 6-month home-based physical activity and diet intervention for rural adults with, or at risk of MetS. The randomised controlled trial was conducted in Albany and surrounding towns, Western Australia, 2014–2015. Participants were screened for MetS using the International Diabetes Federation criteria, and eligible participants were randomly assigned to the intervention (n = 201) or control (n = 200) group. The intervention group received printed and online programme materials and motivational support, and the control group was waitlisted to receive the programme after post-test data collection. Anthropometry, lipid profiles, glycaemic status, and blood pressure were measured at baseline and 6-months post-test. In total, 312 (77.8%) participants completed post-test data collection and were included in the anthropometric analysis, and 274 (68.3%) participants were included in the blood sample analysis. After controlling for confounders, the intervention group significantly improved their triglyceride (−0.10 mM, p = 0.002), total cholesterol (−0.09 mM, p = 0.02), and non-HDL cholesterol (−0.08 mM, p = 0.02) concentrations compared to the control group. Waist circumference (−2.11 cm, p = 0.03), waist-to-hip ratio (−0.01, p = 0.04), weight (−0.70 kg, p = 0.01), and body mass index (−0.20 kg/m^2, p < 0.001) were also improved. These findings suggest that comprehensive home-based prevention programmes that include a combination of dietary and physical activity interventions are a promising means to prevent the onset of chronic disease in rural adults.
Trial registration:anzctr.org.au Identifier: ACTRN12614000512628

1. Introduction

Obesity and its associated chronic diseases are a growing public health concern worldwide. Since the 1980's, global overweight and obesity prevalence has increased by 28% in adults and 47% in children, which equates to an estimated 2.1 billion people (Ng et al., 2014). In Australia, approximately two-thirds (63%) of the population are overweight or obese (Australian Institute of Health and Welfare, 2014) which is an increase of approximately 9% in the last 17 years (Australian Bureau of Statistics, 2011). The proportion of adults aged 50+ who are overweight or obese has reached 70%, indicating that prevalence increases with age (Australian Bureau of Statistics, 2013a). Additionally, the prevalence of overweight/obesity has been rising more so among middle-aged adults living in harder to reach and often neglected rural/remote areas of Australia (Australian Bureau of Statistics, 2011).

The combination of excess weight and older age increases the prevalence of metabolic syndrome, which is defined by the presence of dyslipidaemia, hyperglycaemia, and hypertension (Blaha et al., 2008). Advancing age is a major contributor to all metabolic syndrome parameters (Grundy et al., 2004; Han & Lean, 2006). Prevalence also increases with body mass index (BMI) (Han &; Lean, 2006; Kassi et al., 2011), due to abdominal obesity being common to each of the metabolic syndrome parameters (Zimmet et al., 2005).

Metabolic syndrome is considered a worldwide epidemic (Alberti et al., 2009). It is estimated that approximately one fourth of adults worldwide carry the syndrome (Grundy, 2008). Individuals with metabolic syndrome are at increased risk of developing type 2 diabetes mellitus and cardiovascular disease (Blaha et al., 2008; Salas-Salvado et al.,

Abbreviations: APAN, Albany Physical Activity & Nutrition; ATPIII, National Cholesterol Education Program Adult Treatment Panel III; AUSDRISK, Australian Type 2 Diabetes Risk Assessment Tool; BMI, body mass index; GEE, generalised estimating equation; HDL, high density lipoprotein; IDF, International Diabetes Federation; LDL, low density lipoprotein; MET, metabolic equivalent; RCT, randomised controlled trial.

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http://dx.doi.org/10.1016/j.ypmed.2016.05.012

2008). Of the one million Australians with diagnosed diabetes mellitus (Australian Institute of Health and Welfare, 2014), the majority of cases (85%) are type 2 which is a largely preventable disease (Australian Institute of Health and Welfare, 2014). Australian adults aged 65–74 years have the highest rate (15%) of diabetes compared to other age groups, and the 55–74 year age group has the highest rate of newly diagnosed cases (2.3%) of diabetes in Australia (Australian Bureau of Statistics, 2013b).

There is a high cardiovascular risk associated with individuals who have a metabolic syndrome diagnosis (Barazzoni et al., 2013), often due to the presence or increased risk of type 2 diabetes. For those with type 2 diabetes the risk of stroke is increased 2- to 4-fold, and the risk of myocardial infarction is increased 3- to 4-fold (Kaur, 2014). Diabetes ranks higher as a cause of death in rural and remote areas than major cities (Australian Institute of Health and Welfare, 2014), with the main contributor to higher mortality rates being coronary heart disease (Australian Institute of Health and Welfare, 2014). Other possible adverse health outcomes of metabolic syndrome include polycystic ovary syndrome, Cushing's syndrome, stress, depression, and some cancers (Han & Lean, 2006).

Management of chronic diseases and related health issues becomes difficult once they develop, highlighting the need for an early warning/screening system to protect those at risk (Sherwin & Jastreboff, 2012). The early identification of populations at risk of chronic disease provides an opportunity for the implementation of preventive measures (Australian Institute of Health and Welfare, 2014). In particular, identifying obese individuals at risk of, or with metabolic syndrome residing in rural/remote locations is a clinical priority (Barazzoni et al., 2013).

Implementing effective metabolic syndrome management is essential when considering its documented progression to type 2 diabetes, cardiovascular disease, and other health issues if left unmanaged (Camhi et al., 2010). A systematic review of 13 RCTs with 3907 individuals revealed lifestyle interventions to be more effective than pharmacological therapies at reversing metabolic syndrome (Dunkley et al., 2012), and in turn preventing its progression to cardiovascular disease and type 2 diabetes. It is now documented that all of the clinical markers of metabolic syndrome can be improved with diet and physical activity intervention (Bassi et al., 2014); therefore weight loss via diet and physical activity modification should be the focus of interventions (Mecca et al., 2012).

Effective lifestyle interventions directed at metabolic syndrome use a combination of counselling, motivational support, education, goal setting, and tailored feedback (Brauer et al., 2015; Hartmann-Boyce et al., 2015). A recent systematic review found that the optimal strategies to address metabolic syndrome were motivational support, internet monitoring, and regular personal feedback (Bassi et al., 2014), achieved via home-based self-help interventions. Such interventions may be particularly suitable for disadvantaged rural communities targeting older adults with or at risk of metabolic syndrome (Hartmann-Boyce et al., 2015; McNaughton et al., 2012).

Due to the ageing population and the higher proportion of older adults outside major cities (Australian Institute of Health and Welfare, 2014), rural areas will require more targeted services for older adults in the context of chronic disease prevention (Janus et al., 2007). Home-based interventions offer a solution to the barriers experience by rural populations such as limited access to health services and greater distances to travel to available services (Australian Institute of Health and Welfare, 2014), and are suitable for those who have employment commitments because the programme can be undertaken at any time. The effectiveness of home-based lifestyle interventions for older adults with metabolic syndrome residing in rural/remote Australian regions is under-researched (McNaughton et al., 2012). The Albany Physical Activity and Nutrition (APAN) programme aimed to address this gap by identifying and improving the lifestyle behaviours of rural adults with or at risk of metabolic syndrome. The purpose of the current study was to evaluate the effectiveness of the APAN intervention in terms of improvement in metabolic parameters and cardiovascular risk factors for this disadvantaged population subgroup. The changes in diet and physical activity behaviours have been reported separately (Blackford et al., 2016).

2. Methods

2.1. Study design and intervention

The APAN study was a RCT of a 6 month home-based physical activity and diet intervention, adapted from a 6 month intervention for a similar target group (Burke et al., 2012). The intervention strategies and resources included printed and interactive online programme materials, developed based on the Australian Dietary Guidelines (National Health and Medical Research Council, 2013) and Australia's Physical Activity and Sedentary Behaviour Guidelines (Department of Health, 2014). Participants were encouraged to set goals and self-monitor their progress, and received support from research staff using motivational interviewing techniques (Resnicow & McMaster, 2012). All participants were informed of the study aims and procedures, and provided written informed consent. Details of the study design and intervention have been described previously (Blackford et al., 2015). The study protocol was approved by the Curtin University Human Research Ethics Committee (approval number HR149_2013) and the trial was registered with the Australian and New Zealand Clinical Trials Registry (ACTRN12614000512628).

2.2. Participants

Adults residing in Albany and environs in the Great Southern region of Western Australia were contacted randomly via telephone. Interested participants were screened for study eligibility initially using the Australian Type 2 Diabetes Risk Assessment Tool (AUSDRISK) (Chen et al., 2010), followed by clinical measures obtained at a local clinic. Participants ($n = 401$), aged 50 to 69 years and classified as either having or being at risk of metabolic syndrome, were randomly assigned to a 6 month lifestyle intervention ($n = 201$) or control group ($n = 200$). The participants and recruitment procedure have been previously reported in detail (Blackford et al., 2016).

2.3. Definition of metabolic syndrome

Individuals at an increased cardiovascular risk can be identified using clinical definitions of metabolic syndrome (Blaha et al., 2008). The most current definitions are the National Cholesterol Education Program Adult Treatment Panel III (ATPIII) criteria and the International Diabetes Federation (IDF) criteria (Kassi et al., 2011). The IDF criteria address the causal link between central obesity and the other components of metabolic syndrome by ensuring obesity is an absolute in the screening process (International Diabetes Federation, 2006), and is therefore considered most suitable for clinical practice to prevent and manage obesity-related health issues (Kassi et al., 2011). The IDF definition has therefore been used to define metabolic syndrome in the present study.

The IDF definition (Han & Lean, 2006) includes a large waist circumference as the minimum requirement (waist circumference ≥ 94 cm for men or ≥80 cm for women [Europids, Sub-Saharan Africans, Eastern Mediterranean, Middle East]; ≥90 cm for men or ≥80 cm for women [South Asians, Chinese, Japanese]), plus any two of the following parameters: raised triglyceride level (≥1.7 mM, or treatment for this); reduced high density lipoprotein (HDL) cholesterol (<1.03 mM in males and <1.29 mM in females, or treatment for this); raised blood pressure (systolic ≥ 130 mm Hg or diastolic ≥ 85 mm Hg, or treatment of previously diagnosed hypertension); raised fasting plasma glucose (≥5.6 mM). The purpose of applying the IDF criteria in the present study was to ensure participants with central obesity were recruited to enable assessment of weight management and the associated clinical benefits of chronic disease prevention (Han & Lean, 2006).

Participants were classified as having metabolic syndrome if they met the full IDF criteria stated above. Participants who met the above requirement for central obesity and only satisfied one (instead of two) of the latter four additional conditions specified by IDF were classified as at risk of metabolic syndrome and also included in the present study. The aim of also targeting these individuals was to assess the effectiveness of the intervention at preventing the onset of metabolic syndrome and associated chronic diseases (Kaur, 2014; Hsiung et al., 2014). The full recruitment procedure has been reported previously (Blackford et al., 2016); however a summary is provided in Fig. 1.

2.4. Outcome measures

The primary outcome measures were changes to blood parameters, blood pressure, and anthropometry, measured at baseline and post-test. Fasting blood samples (>10 h) were taken by a phlebotomist at a local pathology lab. Fasting plasma glucose, cholesterol and triglyceride concentrations were measured, and low density lipoprotein (LDL)-, total-, HDL-, non-HDL-cholesterol levels were subsequently determined (Nordestgaard & Varbo, 2014). Remnant cholesterol was also determined due to the associated increased risk of cardiovascular disease (Nordestgaard & Varbo, 2014), as it is understood to be a more likely causal factor than reduced HDL cholesterol (Varbo et al., 2013). Systolic and diastolic blood pressure were measured by a trained researcher using an Omron M5-1 electronic sphygmomanometer. The participant was in a sitting position for 5 min prior to the first measurement. Readings were taken from the upper arm 1 min apart, with a mean value recorded after three measurements (Pickering et al., 2005). Waist and hip circumference were recorded to the nearest 0.5 cm using a plastic measuring tape, and waist-to-hip ratio (waist/hip) was subsequently

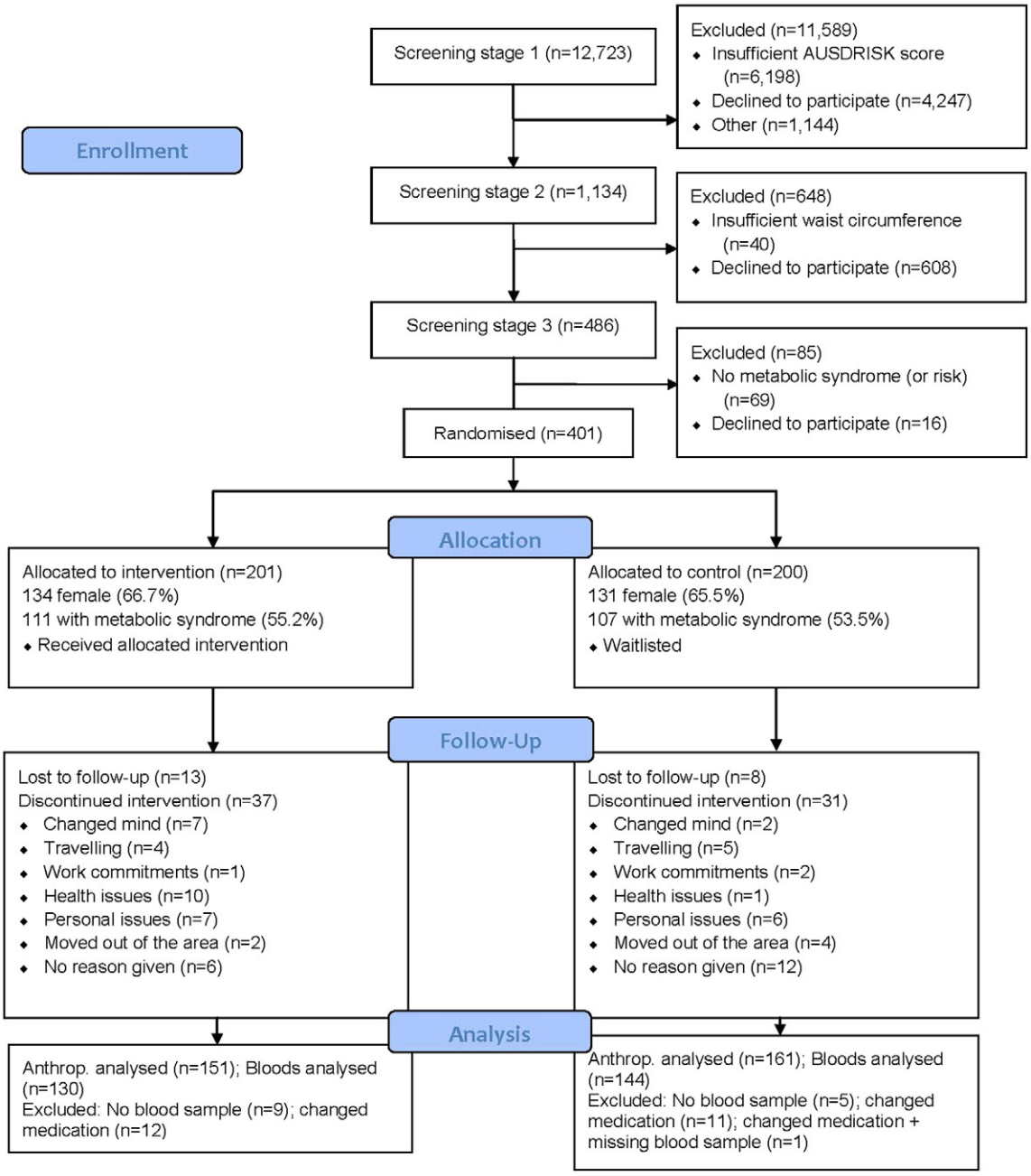

Fig. 1. CONSORT flow diagram Table 1 summarises baseline characteristics of the intervention and control groups. The sample consisted of predominantly females (66.5%) with an overall mean age of 61 years (SD = 5.41). There were no significant differences between the groups at baseline in terms of demographic characteristics, blood parameters, blood pressure, and anthropometric measurements. No differences were observed in comparisons of study completers and study dropouts.

determined (Welborn et al., 2003). Weight was recorded to the nearest 0.01 kg using a Tanita digital scale, and height was recorded to the nearest 0.1 cm using a stadiometer while the participant was barefoot. BMI (weight [kg] / height [m]^2) was subsequently determined.

2.5. Statistical analysis

Descriptive statistics summarised the baseline demographic and lifestyle characteristics, metabolic syndrome parameters, and anthropometric measurements of the sample. Continuous outcome variables were compared between and within groups using independent and paired t tests, with non-parametric Mann–Whitney U tests and Wilcoxon Signed Rank tests applied to variables with skewed distributions. Generalised estimating equation (GEE) models with exchangeable correlation structure were used to analyse repeated measures over time, while accounting for demographic and other potential confounders. Normally distributed continuous variables were assessed using a normal GEE model with identity link, whereas skewed continuous variables were assessed using a gamma GEE model with log link.

3. Results

Fig. 1 presents the CONSORT flow chart, which outlines the study procedure and sample sizes. The initial recruitment phase occurred from October 2013 to December 2014, with post-test measurements completed in August 2015. During the follow-up, 151 (75.1%) intervention and 161 (80.5%) control group participants returned to the clinic for post-test data collection and were available for anthropometric analysis, of which 151 (75.1%) intervention and 159 (79.5%) controls completed the questionnaire and were available for the analysis of demographic characteristics. At post-test, 21 intervention and 17 control participants did not attend the pathology lab for their blood samples or were excluded due to a change in medication from baseline to post-test, resulting in a final sample of 130 (64.7%) intervention and 144 (72.0%) control participants for blood analysis.

Table 1
Baseline characteristics of participants, Albany Western Australia, 2014–2015.

Variable	Intervention group	Control group	p value[a]
	(n = 151)	(n = 159)	
Age (years)	60.5 (5.64)	61.3 (5.18)	0.18
Gender: female	100 (66.2%)	106 (66.7%)	0.93
Employment status			0.30
Full time	78 (51.7%)	65 (40.9%)	
Part time	24 (15.9%)	29 (18.2%)	
Unemployed	5 (3.3%)	7 (4.4%)	
Retired	44 (29.1%)	58 (36.5%)	
Education			0.42
Primary school	3 (2.0%)	2 (1.3%)	
Secondary school	55 (36.4%)	72 (45.0%)	
TAFE/Diploma	52 (34.4%)	46 (28.8%)	
University	41 (27.2%)	39 (24.5%)	
Relationship status: with partner	124 (82.1%)	129 (81.1%)	0.81
Smoking status			0.85
Never	84 (55.6%)	84 (52.8%)	
Ex-smoker	52 (34.4%)	54 (33.8%)	
Occasional smoker	3 (2.0%)	4 (2.5%)	
Daily smoker	12 (7.9%)	17 (10.6%)	
Co-morbidity[b]: yes	92 (60.9%)	104 (65.4%)	0.41
Alcohol drinking: yes	99 (65.6%)	113 (71.1%)	0.96
	n = 130	n = 144	
Metabolic syndrome status			0.66
Metabolic syndrome	66 (50.8%)	77 (46.5%)	
At risk	64 (49.2%)	67 (46.5%)	

[a] t-Test or chi square test between intervention and control groups.
[b] Presence of at least one of 8 common health problems.

Table 2 gives the changes in cardiovascular risk factors within and between intervention and control groups. Significant improvements in triglycerides (−0.1 mM, p = 0.01), total cholesterol(−0.09 mM, p = 0.04), remnant cholesterol (−0.1 mM, p = 0.003), and both systolic (−5.24 mm Hg, p < 0.001) and diastolic blood pressures (−2.34 mm Hg, p = 0.002) were observed for the intervention group from baseline to post-intervention. There were no significant within-group changes in parameters for the control group. The GEE analyses for cardiovascular risk factors are provided in Table 3. After controlling for demographic and other potential confounders, significant improvements in the intervention group relative to the control group were observed for triglycerides (p = 0.002), total cholesterol (p = 0.02), non-HDL cholesterol (p = 0.02), and remnant cholesterol (p = 0.03) through the group x time interaction term.

Table 4 gives the univariate comparisons of anthropometrics between intervention and control groups. The intervention group significantly improved in waist circumference (−2.11 cm, p < 0.001), hip circumference (−1.25 cm, p < 0.001), waist-to-hip ratio (−0.01, p = 0.002), weight (−0.7 kg, p < 0.001), BMI (−0.2 kg/m^2, p < 0.001), and body fat (−1.5%, p < 0.001) from baseline to post-intervention. Table 5 provides the results from the GEE analyses of anthropometric outcome measures. Relative to the control group, the intervention group significantly improved in waist circumference (p = 0.03), waist-to-hip ratio (p = 0.04), weight (p = 0.01), and BMI (p < 0.001) through the group x time interaction, after controlling for potential confounders.

4. Discussion

There is a high prevalence of poor diet, physical inactivity, and overweight/obesity for older adults residing in rural areas of Australia (Williams et al., 2012). Consequently, the prevalence of metabolic syndrome, type 2 diabetes, and chronic disease is higher in these areas (Australian Institute of Health and Welfare, 2014), highlighting the need to develop interventions targeting this group (Janus et al., 2007). This RCT examined the effectiveness of the APAN programme for improving the metabolic syndrome parameters of participants, as a result of significantly improved dietary and physical activity outcomes (Blackford et al., 2016). The findings demonstrate that 6-months programme engagement in physical activity, nutrition, and weight management significantly improved several metabolic syndrome parameters and cardiovascular risk factors for the participants. Specifically, triglycerides, total-, non-HDL- and remnant-cholesterol were all improved for the intervention group when compared to the control group, and similar improvements were evident in anthropometric measurements such as waist circumference, waist-to-hip ratio, weight, and BMI.

Aerobic exercise and dietary modifications are considered to be effective interventions for metabolic syndrome, due to the associated improvements in blood pressure, waist circumference, triglycerides, and HDL cholesterol (Pattyn et al., 2013). Motivational interviewing combined with regular monitoring and feedback are recommended strategies for individuals with metabolic syndrome (Bassi et al., 2014), all of which had been implemented in the APAN programme. These strategies supported behaviour change, resulting in the intervention group moderately increasing metabolic equivalent (MET) minutes of moderate intensity physical activity per week, significantly increasing fibre intake and vegetable serves per day, and decreasing fat intake when compared to the control group (Blackford et al., 2016). These reported behaviour changes impacted on the individual metabolic syndrome parameters and cardiovascular risk factors.

It is recommended that weight reduction via dietary and physical activity improvements should be the primary intervention goal for individuals with metabolic syndrome due to the association between weight loss and lower cholesterol, triglycerides, glucose, and blood pressure, and increased HDL cholesterol (Blaha et al., 2008; Grundy et al., 2004). Specifically, a reduction in abdominal fat, measured by

Table 2
Comparison of changes in metabolic syndrome parameters and cardiovascular risk factors between intervention and control groups, Albany Western Australia, 2014–2015.

Outcome	Intervention group (n = 130)		p value[a]	Control group (n = 144)		p value[b]	p value[c]	p value[d]
	Baseline	Post		Baseline	Post			
Triglycerides (mM)[e]	1.48 (0.79)	1.36 (0.75)	0.01	1.37 (0.60)	1.47 (0.68)	0.02	0.19	0.09
Glucose (mM)	5.01 (0.46)	5.06 (0.53)	0.19	5.04 (0.49)	5.11 (0.56)	0.07	0.60	0.48
HDL cholesterol (mM)	1.46 (0.42)	1.45 (0.39)	0.44	1.46 (0.42)	1.44 (0.38)	0.45	0.88	0.89
Total cholesterol (mM)	5.56 (0.97)	5.47 (1.02)	0.04	5.40 (1.10)	5.45 (1.03)	0.29	0.19	0.87
LDL cholesterol (mM)	3.42 (0.81)	3.34 (0.95)	0.15	3.32 (0.93)	3.34 (0.90)	0.56	0.31	0.99
Non-HDL cholesterol (mM)	4.10 (0.89)	4.02 (0.96)	0.07	3.94 (1.01)	4.01 (9.33)	0.16	0.17	0.90
Remnant cholesterol (mM)[e]	0.60 (0.30)	0.50 (0.30)	0.003	0.60 (0.40)	0.60 (0.30)	0.06	0.43	0.05
Systolic blood pressure (mm Hg)	138.54 (14.05)	133.30 (14.85)	<0.001	138.56 (14.36)	136.32 (16.10)	0.07	0.99	0.09
Diastolic blood pressure (mm Hg)	87.21 (9.02)	84.87 (9.19)	0.002	85.99 (8.75)	84.96 (9.01)	0.15	0.26	0.95

[a] Paired t-test between baseline and post-test for the intervention group.
[b] Paired t-test between baseline and post-test for the control group.
[c] Independent t-test between intervention and control group at baseline.
[d] Independent t-test between intervention and control group at re-test.
[e] Non-parametric tests applied due to skewed distributions.

waist circumference, is associated with improved metabolic risk profile and reduced risk of cardiovascular disease (Lemieux et al., 2007). The significant reduction in waist circumference, waist-to-hip ratio, and blood lipids for the APAN intervention group suggests that the observed improvements in dietary intake in combination with increased physical activity (Blackford et al., 2016) not only assisted with improved body composition, but also led to improvements in individual metabolic syndrome parameters (Grundy et al., 2004). Abdominal fat mass is suggested to have a direct intermediary role in metabolic syndrome development (Han & Lean, 2006); therefore the observed reduction in waist circumference and other measures of body composition for the APAN intervention group may have directly influenced other metabolic syndrome parameters.

Individuals at the upper end of the normal BMI range are at a substantially increased risk of metabolic syndrome; therefore BMI maintenance at 21–22 kg/m^2 is recommended for those at risk of, or with metabolic syndrome (Han & Lean, 2006). A systematic review indicated that lifestyle interventions resulting in even modest weight loss can effectively improve blood lipids (Aucott et al., 2011). The intervention group of the APAN study demonstrated significant weight loss relative to the control group, as well as a significant reduction in BMI. The significant reduction in triglycerides, total- non-HDL- and remnant cholesterol for the APAN intervention group is therefore promising, considering the important role of blood-lipid regulation via dietary improvements, increased physical activity, and/or weight loss in prevention and treatment of metabolic syndrome and related chronic diseases (Aucott et al., 2011).

Even without weight loss, moderate intensity physical activity has been found to lower triglycerides (Ahmed et al., 2012). The mean moderate MET minutes per week reported by the APAN intervention group significantly increased from 300 (SD = 585.0) to 480 (SD = 850.0) minutes per week ($p < 0.001$) (Blackford et al., 2016), which suggests that improvements in triglycerides may have been observed regardless of weight loss. A systematic review reported significant changes in lipids when moderate intensity activities were performed for more than 150 minutes per week (Tambalis et al., 2009). The APAN intervention participants significantly reduced their triglycerides, which is consistent with a meta-analysis of RCTs that examined the effect of aerobic exercise on lipids (Kelley et al., 2005). The meta-analysis found that aerobic exercise effectively decreased triglycerides in overweight and obese adults (Kelley et al., 2005), which is consistent with other studies (Lin et al., 2015).

In addition to the beneficial effects on triglycerides, physical activity can also favourably influence other lipids. Non-HDL cholesterol includes all lipids apart from HDL cholesterol, and is considered a more reliable cardiovascular risk indicator than LDL cholesterol alone (Gordon et al., 2014). The APAN intervention group significantly reduced their non-HDL cholesterol concentrations relative to the control group, suggesting that the combination of increased physical activity and weight loss may have had a beneficial effect on cardiovascular risk. However, previous meta-analyses have found that non-HDL cholesterol could be significantly reduced as a result of aerobic exercise independent of weight loss (Gordon et al., 2014). Consequently, the reduction among the APAN participants may have occurred as a result of increased physical activity alone.

In addition to physical activity, many of the metabolic syndrome and cardiovascular risk factors are influenced by the Western diet, and can be reversed by improvements in dietary intake (Blaha et al., 2008). A

Table 3
GEE analysis of metabolic syndrome parameters and cardiovascular risk factors before and after intervention (n = 274), Albany Western Australia, 2014–2015.

	Group: intervention		Time: post		Grouptime	
	Coefficient (SE)	p*	Coefficient (SE)	p*	Coefficient (SE)	p*
Triglycerides (mM)[a]	0.08 (0.05)	0.14	0.07 (0.03)	0.02	−0.13 (0.04)	0.01
Glucose (mM)[b]	−0.04 (0.06)	0.54	0.06 (0.04)	0.08	−0.01 (0.05)	0.79
HDL chol (mM)[b]	0.04 (0.04)	0.33	−0.01 (0.02)	0.47	−0.00 (0.02)	0.93
Total chol (mM)[b]	0.21 (0.12)	0.07	0.06 (0.05)	0.26	−0.15 (0.07)	0.02
LDL chol (mM)[b]	0.12 (0.10)	0.24	0.02 (0.04)	0.55	−0.11 (0.07)	0.13
Non-HDL chol (mM)[b]	0.17 (0.11)	0.13	0.07 (0.05)	0.14	−0.15 (0.06)	0.02
Remnant chol (mM)[a]	0.10 (0.06)	0.10	0.06 (0.03)	0.03	−0.13 (0.06)	0.03
Systolic BP (mm Hg)[b]	−0.83 (1.65)	0.62	−2.19 (1.22)	0.07	−3.09 (1.64)	0.06
Diastolic BP (mm Hg)[b]	0.52 (1.02)	0.61	−0.99 (0.71)	0.17	−1.35 (1.01)	0.18

[a] Gamma generalised estimating equation model with log link.
[b] Normal generalised estimating equation model with identity link.
* Adjusted for age, gender, relationship status, education level, employment status, co-morbidity, alcohol drinking, and smoking status.

Table 4
Comparison of changes in anthropometric measurements between intervention and control groups, Albany Western Australia, 2014–2015.

Outcome	Intervention group (n = 151)		p value[a]	Control group (n = 161)		p value[b]	p value[c]	p value[d]d
	Baseline	Post		Baseline	Post			
Waist circumference (cm)	102.67 (13.58)	100.56 (13.84)	<0.001	101.41 (12.93)	100.53 (12.69)	0.02	0.40	0.78
Hip (cm)	112.38 (11.99)	111.13 (12.04)	<0.001	111.57 (11.05)	110.57 (10.95)	0.02	0.54	0.67
Waist-to-hip ratio (waist/hip)	0.91 (0.08)	0.90 (0.08)	0.002	0.91 (0.08)	0.91 (0.08)	0.82	0.56	0.58
Weight (kg)[d]	85.20 (22.60)	84.50 (23.70)	<0.001	85.30 (21.90)	86.40 (22.00)	0.12	0.88	0.74
BMI (kg/m^2)[d]	29.55 (6.93)	29.35 (7.00)	<0.001	29.80 (7.05)	29.70 (6.90)	0.10	0.88	0.68
Body fat (%)[d]	40.20 (11.70)	38.70 (11.35)	<0.001	38.80 (12.75)	39.10 (12.80)	0.75	0.60	0.77

[a] Paired t-test between baseline and post-test for the intervention group.
[b] Paired t-test between baseline and post-test for the control group.
[c] Independent t-test between intervention and control group at baseline.
[d] Independent t-test between intervention and control group at re-test.
[d] Non-parametric tests applied.

diet rich in fruits, vegetables, and fibre is recommended for individuals with metabolic syndrome (Blaha et al., 2008). As such these recommendations were incorporated into the APAN programme strategies. Diets high in saturated fat are associated with oxidative stress and elevated LDL and total cholesterol, but not diets high in polyunsaturated fat (Esposito et al., 2004). Additionally, increased consumption of fruit, vegetables, and fibre appear to reduce inflammation (Kaur, 2014; Esposito et al., 2004). Implementation of the APAN programme effectively increased fibre and vegetable intake, and reduced the fat intake among the intervention group participants (Blackford et al., 2016), which might have reduced overall oxidative stress. It should be noted that total- and non-HDL cholesterol were significantly lowered for the intervention group.

The improvement of non-HDL cholesterol and triglycerides for the APAN intervention group suggests that improvements in dietary behaviours in combination with marginal improvements in moderate physical activity and weight loss may have reduced cardiovascular disease risk for participants. As a predictor of cardiovascular disease, non-HDL cholesterol is more relevant than LDL cholesterol, particularly in combination with elevated triglycerides (Blaha et al., 2008). The APAN intervention significantly reduced triglycerides and non-HDL cholesterol, suggesting that it is important to implement changes in both diet and physical activity to reduce cardiovascular risk.

4.1. Strengths and limitations

A major strength of the current study is the recruitment procedure implemented. There is a paucity of interventions that have used the IDF criteria to diagnose metabolic syndrome, which require central obesity to be a characteristic of participants (Higgins & Green, 2011; Lin et al., 2014). Our use of the IDF definition enabled the identification of individuals with a large waist circumference and ensured abdominal obesity and related risks were included as outcome measures (Lin et al., 2014), considering abdominal obesity and insulin resistance are the major underlying risk factors for metabolic syndrome and its components (Grundy et al., 2005). Previous reviews of metabolic syndrome trials have highlighted the need to utilise the current evidence and provide up-to-date guidance on the use of the IDF criteria to define and screen for metabolic syndrome (Dunkley et al., 2012; Lin et al., 2014). The IDF criteria is useful in large population groups because waist circumference as the minimum requirement provides a simple and low-cost screening process that can be performed at any location (Zimmet et al., 2005; Dhaliwal et al., 2014).

A limitation of the study was the brief duration of the intervention. There is a need to develop, evaluate, and disseminate strategies that effectively promote weight maintenance via lifestyle changes (Eakin et al., 2010). Although 6-month interventions are deemed to be long enough to reflect behaviour change (Stiggelbout et al., 2006), older adults often require a sufficient dose to ensure behaviour change is maintained, which can be challenging in the long-term (Burke et al., 2008). Short-term weight loss programmes are effective in the target group; but participants tend to regain weight once such programmes end (Bassi et al., 2014). Considering the relatively brief duration of the APAN intervention (6-months), it is recommended that longer-term studies are conducted to determine the sustainable effectiveness of similar lifestyle programmes (Korczak et al., 2011).

5. Conclusion

The APAN study has demonstrated the potential benefits of identifying and managing adults aged 50 to 69 years who have or are at risk of metabolic syndrome in a rural community. The home-based programme effectively improved dietary and physical activity behaviours of participants, which in turn improved individual metabolic syndrome parameters and cardiovascular risk factors. Comprehensive home-based prevention programmes that incorporate a combination of dietary and physical activity improvements are promising to prevent the onset of chronic disease in high risk population groups.

Table 5
GEE analysis of anthropometric outcomes before and after intervention (n = 312), Albany Western Australia, 2014–2015.

	Group: intervention		Time: post		Group x time	
	Coefficient (SE)	p[c]	Coefficient (SE)	p[c]	Coefficient (SE)	p[c]
Waist circumference (cm)[a]	1.16 (1.33)	0.38	−0.87 (0.38)	0.02	−1.17 (0.53)	0.03
Hip (cm)[a]	0.66 (1.26)	0.60	−0.98 (0.42)	0.02	−0.26 (0.50)	0.60
Waist-to-hip ratio (waist/hip)[a]	0.01 (0.01)	0.34	0.00 (0.00)	0.82	−0.01 (0.00)	0.04
Weight (kg)[b]	0.01 (0.02)	0.69	0.00 (0.00)	0.18	−0.01 (0.00)	0.01
BMI (kg/m)[b]	0.01 (0.02)	0.57	0.00 (0.00)	0.16	−0.01 (0.00)	<0.001

[a] Normal generalised estimating equation model with identity link.
[b] Gamma generalised estimating equation model with log link.
[c] Adjusted for age, gender, relationship status, education level, employment status, co-morbidity, alcohol drinking, and smoking status.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

This study was partly funded by South West Medicare Local. We are grateful to the residents of Albany and surrounding towns who participated in the study.

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