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RUNNING HEAD: Resilience Training for Diabetes

A Pilot Evaluation of a Group Acceptance and Commitment Therapy (ACT)-Informed Resilience Training Program for People with Diabetes

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Abstract

Objective. Individuals with diabetes can experience poor mental health, which is associated with poor physical health outcomes. Few studies have examined interventions to increase resilience and related protective factors in people with diabetes. The purpose of this study was to undertake a pilot evaluation of an Acceptance and Commitment Therapy (ACT)-informed group resilience training program for people with diabetes. **Methods.** We delivered the program in community venues to 20 people with diabetes, with 10 x 2 hour weekly sessions. Assessment was conducted at pre- and post-intervention using questionnaires and pedometers. **Results.** There were significant improvements in resilience, psychological flexibility, positive affect, valued living, physical activity and sedentary behaviour, and significant decreases in depression and stress (p<.01). Improvements in mindfulness, diabetes-related distress and anxiety approached significance (p<.05). Feasibility and acceptance data showed high program engagement and satisfaction, and self-reported improvements that supported the statistically significant changes. **Conclusions.** ACT-informed resilience training is a promising means to strengthen resilience and related protective factors, and improve mental health in this population and warrants further evaluation in randomised controlled trials.

Keywords

acceptance and commitment therapy, diabetes, resilience, resilience training, quality of life

Key Points

What is already known about this topic

1. Most psychological interventions for people with diabetes have focused on reducing distress, rather than enhancing resilience and related protective factors.
2. Resilience has been identified as an important resource for people with diabetes.
3. Few published studies have evaluated resilience training for this population.

What this topic adds

1. This study evaluated the effectiveness and feasibility of an Acceptance and Commitment Therapy (ACT)-informed group resilience training program for people with diabetes.
2. Findings provide preliminary support for the utility of an ACT-informed group resilience training program for improving resilience, distress and a range of protective factors in people with diabetes.
3. ACT-informed resilience training delivered in the community was feasible, acceptable, and well received by these people with diabetes.

Diabetes is a chronic condition with a demanding treatment regime that places substantial psychological, physical, and social stress on the individual. The negative impacts of diabetes on functioning in many life domains is clearly established (Acchab et al, 2008). Work, social functioning, relationships, and emotional and physical wellbeing can be compromised, with high rates of depression and anxiety (Campayo et al, 2014; Holt, de Groot & Golden, 2014; Khuwaja et al, 2010; Smith et al, 2013; Svenningsson et al., 2011; Tan et al, 2015). Adults with diabetes have a higher prevalence (43%) of distress than those without diabetes (Australian Institute of Health and Welfare, 2011). This, in turn, adversely affects diabetes self-management and health outcomes and increases the burden of disease.

Most psychological interventions for people with diabetes have focused on reducing distress, rather than enhancing resilience and related protective factors, which are likely to provide long-term benefits (Pascoel et al, 2017). Resilience is the ability to 'bounce back' from, and successfully adapt to stressful life events, and involves a process of adaptation to stress or trauma that is influenced by an individual's internal and external resources (Windle, Bennett & Noyes, 2011). Resilience is an important predictor of quality of life (QoL) in people with physical disability and illness, and has been shown to ameliorate the adverse effects of fatigue and pain on QoL in a mixed disability sample (Terrill et al, 2016). A review identified five key resilience protective factors: positive emotions, cognitive flexibility (including acceptance), religion/spirituality (a framework for life meaning), social support and active coping (including exercise) (Southwick, Vythilingam, & Charney, 2005). Fostering resilience and its protective factors in individuals with diabetes is likely to improve the ability to adapt to illness stressors and result in improved QoL (Bradshaw et al., 2007).

A review of resilience training interventions for people with chronic diseases showed that there are few studies on resilience *training* with this population and that most neglected resilience protective factors (Kim, Lim, Kim & Park, 2018). We know of only two published resilience training studies for adults with diabetes. One program involved 10 x 90-minute group sessions over five weeks, with a focus on developing positive health behaviours via four components: self-efficacy, locus of control, purpose in life and social support (Bradshaw et al., 2007). The experimental group (n=37), relative to the usual care comparison group (n=30), improved in positive coping, diabetes-related stress, self-awareness, diabetes self-management, healthy eating, and physical activity at three-month follow-up (Bradshaw et al., 2007). The Diabetes Coaching Program involved 4 x 2 hour weekly class sessions focused on resilience education and diabetes self-management (predominantly diabetes-specific nutrition education) and 8 x 1.5 hour biweekly, informal, non-structured support group sessions (Steinhardt et al, 2009). Results (n=12) showed improvements from baseline to post-intervention on measures of diabetes empowerment and self-management; but not resilience, perceived stress, or coping (Steinhardt et al, 2009).

Most of the psychological interventions used with people with diabetes have been based on cognitive and behaviour therapy (CBT). Recent variants of CBT have evolved called ‘third generation’ CBTs. One of the most widely used and researched of this group is Acceptance and Commitment Therapy (ACT; Hayes, Strosahl & Wilson, 2011). However, few studies have applied ACT and other third generation CBTs to people with diabetes. Broadly, the goal of ACT is to increase psychological flexibility, which involves behaving consistently with one’s chosen values even with unwanted intrusive internal experiences like emotional discomfort or self-critical thinking (Hayes et al., 2011). Psychological flexibility is the cornerstone of psychological health and is related to resiliency (Kashdan & Rottenberg, 2010). As such, an ACT intervention can increase resilience by improving an individual's psychological flexibility. According to the ACT framework, six core processes enhance psychological flexibility: (1) acceptance: the active awareness of internal experiences without changing their frequency or form; (2) cognitive defusion: maintaining psychological distance from mental experiences (e.g., thoughts) rather than taking them literally or suppressing them; (3) contact with the present moment: ongoing non-judgmental and responsive awareness of the present moment (cf. mindfulness); (4) self-as-context: flexible perspective-taking enabling awareness of one's own flow of experiences, without attachment to them and without them unduly influencing behaviour; (5) values: freely chosen verbally constructed and personally meaningful life directions; (6) committed action: values-guided effective action. In his review of stress management interventions for diabetes, Morris (2011) recommended ACT-based interventions as an alternative approach to CBT, noting the benefits of mindfulness, acceptance and values.

The ACT processes are likely to promote resilience through increasing values-based actions even in the presence of emotional and mental discomfort (Thompson, Arnkoff, & Glass, 2011; Hubert-Williams, Storey, & Wilson, 2015). ACT-based interventions have been associated with increases in resilience and related protective factors (e.g., Pakenham, Mawdsley, Brown, & Burton, 2018). In addition, mindfulness and acceptance, core processes in ACT have been shown to increase resilience (e.g., Thompson et al, 2011).

The research on ACT for adults with diabetes is still emergent and has not focused on resilience as a key outcome. Three randomised controlled trials of group ACT-based interventions showed that compared to control groups, the ACT participants showed greater improvements in diabetes self-management (Gregg et al., 2007; Hoseini et al., 2014; Shayegian et al., 2016), treatment adherence (Gregg et al., 2007) and effective coping strategies (Shayegian et al., 2016). In a quasi-experimental study, an ACT group-based intervention was associated with improvements in mental health for women with Type II diabetes (Kaboudi et al., 2017). Focusing on one of the core ACT processes, a systematic review of mindfulness-based interventions for diabetes showed that such interventions were effective in reducing anxiety, depression and distress, but demonstrated mixed outcomes for improving diabetes-related physiological outcomes (Noordali et al., 2017).

The intervention used in this study was the group-based REsilience for Adults everyDaY (READY) Program. READY is an ACT-informed generic resilience training program that can be tailored to specific contexts (Burton et al., 2010) and its application to people with diabetes is evaluated in the present study. Previous evaluations of READY have shown improvements in resilience and QoL, and resilience related protective factors including psychological flexibility, physical activity, mindfulness, subjective wellbeing, and health behaviours in a tertiary education worksite sample (Burton et al., 2010), colorectal cancer survivors (Hawkes et al., 2013; Hawkes et al., 2014), and people with multiple sclerosis (Pakenham et al., 2018). The READY program is described in more detail elsewhere (Burton, Pakenham, & Brown, 2009). It targets the five key resilience protective factors identified by Southwick et al's (2005) review: psychological flexibility, life meaning, physical activity, positive emotions and social connectedness.

In summary, people with diabetes are at risk for compromised QoL and elevated distress. Resilience is a process of positive adjustment to adversity and is an important predictor of QoL in people with physical disability and illness. ACT is a potentially effective intervention for promoting resilience and related protective factors (Pakenham et al, 2018). Furthermore, central to ACT are mindfulness and acceptance processes, which are related to greater resilience. In addition, ACT is based on a model of psychological flexibility; a construct which is related to resilience. There are therefore numerous potential pathways by which ACT could promote resilience and related protective factors. The resilience training program evaluated in the present study uses the six ACT processes to cultivate resilience and related protective factors.

The first aim of the present study was to explore the effectiveness of the READY Program for people with diabetes. We predicted that participants would show significant pre- to post-intervention increases in resilience and decreases in distress, which constituted the primary outcomes. We also expected increases in the resilience protective factors of psychological flexibility, mindfulness, valued living, positive affect and physical activity, which constituted the secondary outcomes. The second aim was to explore the feasibility and acceptability of the READY Program when delivered in the community to people with diabetes and investigate the suitability of a battery of measures for assessing the primary and secondary outcomes that could be included in future clinical trials of READY for diabetes.

Method

This study evaluated the READY Program (Burton et al., 2010) using a single group intervention condition design with pre- and post-intervention assessments. Data were collected via questionnaires and speedometers'. The study protocol was approved by The University of Queensland ethics committee (clearance ID: #2012000495).

Participants and Recruitment

Participants were recruited via Diabetes Australia (Queensland) e-newsletters, a university staff e-newsletter, a radio interview, and flyers distributed through General Practitioners, pharmacies, and a hospital diabetes clinic. Inclusion criteria were a self-reported diagnosis of Type I or Type II Diabetes, age greater than 18 years, fluency in English, and able to attend the weekly community-based sessions. A total of 56 people responded, all of whom were eligible and invited to participate, and of these, 28 declined participation (did not respond to further information or stated that program times, locations or dates did not suit). Of the 28 individuals offered the intervention, eight withdrew prior to commencement, and 20 participants completed the pre- and post-intervention assessments.

The mean age of participants was 54 years (*SD* = 12.78; range 24 - 74), 70.0% were female and 75% were born in Australia. Over half the participants (60.0%) had vocational qualifications (e.g., TAFE, apprenticeship), 25% had university education, and 60% were engaged in part-time or full-time paid employment. Most (75%) of participants stated that it was difficult all or most of the time to manage on their income. Most (70.0%) participants had Type II diabetes. The mean BMI (derived from self-reported height and weight) was 33.07 (*SD* = 10.21). The majority of participants self-reported their general health as 'good'

(35.0%), 'fair' (25.0%), or 'poor' (35.0%), with only one participant self-rating their health as 'very good', and no participants rated their health as 'excellent'.

Intervention

Ten of the eleven standard READY program modules were used in the present study. The mid-program review was excluded because of time constraints. Participants received a workbook that includes written notes, critical reflection and structured learning activities to complete, and a CD of guided mindfulness meditations. Specific reflection and learning activities comprise the READY Personal Plan, which is a personalised resource to help participants apply the generalised information to their specific context and individual style. Details of the program content are summarised in Table 1.

Procedure

The READY Program (Burton et al., 2010) was delivered in 10 group weekly sessions to three separate groups of participants held in community locations (e.g., local library and church hall) in Brisbane, Australia. The first 8 sessions were each two hours in duration and the last two were each one hour. Measures were administered to participants by the program facilitator at the start of the first session and at the end of the last session. The group facilitator was a postgraduate clinical psychology student with formal training in ACT, who received fortnightly group peer supervision from the READY Program authors for the duration of the program delivery. Intervention fidelity, although not directly assessed, was monitored through this regular supervision and supported by the use of the READY Program Facilitators Manual.

Measures

Resilience. The 15-item Resilience Scale (Neill & Dias, 2001) assessed resilience. Items are rated on a 7-point scale (1 *disagree* to 7 *agree*), and summed; higher scores indicate higher resilience.

Distress. *Diabetes-related distress* was assessed with the 20-item Problem Areas in Diabetes scale (Polonsky et al., 1994). The scale measures global emotional adjustment to diabetes (Welch et al., 1997). Items are rated on a 5-point scale (0 *not a problem* to 4 *serious problem*) where higher scores indicate greater emotional distress. *Depression, anxiety and stress* were assessed with the standardised widely used 21-item Depression Anxiety Stress Scale (Lovibond & Lovibond, 1995). Items are scored on a 4-point scale (0 *not at all* to 3 *most of the time*) and summed, where higher scores indicate greater distress (Lovibond & Lovibond, 1995).

Psychological flexibility. The Acceptance and Action Questionnaire II (Bond et al., 2011) assessed psychological flexibility. Seven items are rated on a 7-point scale (1 *never true* to 7 *always true*) and summed. Items were reverse scored so that higher scores indicate greater psychological flexibility.

Positive affect. The positive affect subscale of the Positive and Negative Affect Schedule (Watson & Clark, 1988) assessed positive emotions. Twenty items are rated on a 5 point scale (1 *very slightly or not at all* to 5 *extremely*) and summed, with higher scores indicating a greater positive affect.

Mindfulness. The Mindful Attention Awareness Scale (Brown & Ryan, 2003) measured mindfulness. Fifteen items are rated on a 6-point scale (1 *almost always* to 6 *almost never*) and responses are summed; higher scores reflect a greater mindfulness.

Values. The Valued Living Questionnaire (Wilson & Groom, 2002) was used to measure the importance of certain life domains and the consistency of living according to values in these domains. Sixteen items are rated on a 10-point scale (1 *not at all* to 10 *extremely*) where higher scores indicate greater importance and consistency. A valued living composite is calculated by multiplying the importance and consistency scores for each domain then establishing the mean of these products (Wilson et al., 2010).

Physical Activity. Items from The Active Australia Survey (Australian Institute of Health and Welfare, 2003) were used to assess the time spent in each of walking, vigorous intensity activity, and moderate intensity activity in the previous week. The total time spent in physical activity (weighted minutes/week) was derived by summing responses, with vigorous activity weighted by two to account for the higher intensity (Australian Institute of Health and Welfare, 2003). Pedometers (Yamax Digiwalker SW700, Yamax Corporation, Tokyo, Japan), were used as an objective measure. Participants were asked to wear the pedometer during all walking hours for seven consecutive days and record the number of steps taken each day, and the time the pedometer was worn each day. Valid data was defined as when the pedometer was worn more than nine hours of the day. The step counts per (valid) day were summed and then averaged across the number of days to develop a mean step count per day. The 5-item *Sitting Time Questionnaire* (Marshall et al, 2009) assessed time spent sitting (sedentary behaviour) on a usual day during the past week in each of five domains: travelling, working, watching television, using a computer, or other leisure time. Sitting time (mins/day) was derived by summing data across domains.

Program Feasibility and Acceptability. Participant attendance records were kept for each session by the facilitator, and reasons for non-attendance were recorded at subsequent sessions. The post-intervention questionnaire included items to obtain participant feedback on the program. Five items required participants to rate their level of agreement (1 *strongly disagree* to 5 *strongly agree*) with statements gauging program-related satisfaction, helpfulness and enjoyment, likelihood of recommending the program to others, and the extent to which they believed their resilience had increased. Three open-ended questions inquired about the most helpful *READY* program skills, the impact of the program on their management of diabetes, and suggested improvements to the program.

Data Analysis

The Statistical Package for the Social Sciences Version 19 (SPSS-19) was used for all analyses. Regarding examination of changes from pre- to post-intervention on the primary and secondary outcomes both parametric and non-parametric analyses were conducted due to the mix of normally and non-normally distributed data across the outcome variables. Both sets of analyses yielded an identical pattern of results. Given the similarity in results, parametric analyses are reported. Hence, results of the paired *t*-tests are reported. Although a pilot study, given the number of planned comparisons, a more stringent significance level of $p<0.01$ was applied to reduce the probability of Type II error. Cummins' (2012) recommendations were used to include and interpret effect sizes and their confidence intervals (CI), where .0 - .1 is a non-important effect size, .1 - .3 equals a small to medium effect size, .3 - .5 is a medium to large effect size, and greater than .5 equals a large effect size. Qualitative data from the open-ended questions gauging intervention feasibility and acceptability were analysed using Braun and Clarke's (2006) methodology for thematic analysis.

Results

The results of pairwise *t*-tests are summarised in Table 1, including descriptive data (means and standard deviations) and relevant statistics (t values, r^2 and confidence intervals).

Changes in Primary and Secondary Outcomes

Consistent with predictions related to the first study aim, there were significant improvements in the primary outcomes. Specifically, there were pre- to post-intervention increases in resilience, and decreases in depression and stress ($p<0.01$), and a trend towards improvements (decreases) in diabetes-related distress and anxiety ($p<0.05$). Also as expected there were significant improvements (increases) on the resilience protective factors of positive affect, psychological flexibility, valued living and pedometer assessed physical activity, and decreased self-reported sitting time/day ($p<0.01$). The increase in mindfulness approached significance ($p<0.05$). There was a non-significant positive trend in self-reported time spent in physical activity.

The improvement in resilience evidenced a medium effect size. The effect sizes of improvements for all other variables were small to medium: distress; diabetes-related distress; depression; anxiety; stress; positive affect; psychological flexibility; valued living; self-reported activity (minutes per week); step count; and self-reported sitting time.

Feasibility and Acceptability

Most participants (90.0%) attended more than half the program and over half the participants (55.0%) attended more than 80.0% of sessions. Two participants (10.0%) attended 40.0% or less of the sessions. The most common reasons given for missing sessions were time conflicts with work and family demands.

Participant feedback on the program was very positive. The mean ratings for program-related satisfaction (M = 4.70; SD = .47), helpfulness (M = 4.45; SD = .60) and enjoyment (M = 4.75; SD = .44) were all close to the highest rating of five. Participants rated very highly the extent to which the program had increased their resilience (M = 4.60; SD = .50). The majority nominated ACT skills as most helpful, in particular, defusion, mindfulness and acceptance. All participants agreed that they would recommend the program to others with diabetes. Suggested program improvements from five participants were to include more diabetes specific information (including referral options), reduce the duration of the program, and conduct the program online.

The majority of participants described positive impacts of the program in four broad areas: improved ability to manage the illness (n = 7; e.g., “I am more aware of bad habits and how to not do them”); increased motivation to manage diabetes effectively (n = 6; e.g., “increased my determination to take my health seriously”); improved ability to cope with diabetes (n = 3; e.g., “feeling better able to cope with the diabetes”); and increased acceptance (n = 3; e.g., “more accepting of limitations”). One participant was unsure whether the program had an impact on diabetes management, and another stated that the program had no such impact.

Discussion

As predicted, participants attending the READY Program showed pre- to post-intervention improvements in resilience, distress and the resilience protective factors: psychological flexibility, positive emotions, values and physical activity. Program attendance showed good intervention engagement and participant feedback evidenced high satisfaction with the Program and self-reported improvements that converged with the statistically significant intervention effects.

This study showed improvements in distress that were consistent with improvements shown in prior resilience training research with non-diabetes groups (e.g., Dusek et al., 2009; Sood et al., 2011) including previous evaluations of the READY Program (e.g., Pakenham et al, 2018). Similarly, prior evaluations of READY with chronically ill and non-clinical samples have also shown increases in resilience (Pakenham et al, 2018), and related protective factors including psychological flexibility (Hawkes et al., 2013, Pakenham et al, 2018, Burton et al., 2010), mindfulness, valued living, physical activity and positive emotions (Burton et al, 2010). In the present study, the strongest improvement was evident for resilience with a moderate effect size, and the effect sizes for changes on the other outcomes were in the small to medium range.

Importantly, in the present study the statistically significant improvements in the primary and secondary outcomes were reflected in the participant's qualitative feedback. The majority of participants reported that the program had helped them to become more resilient and to better manage their diabetes. Program feasibility was further supported by the high intervention satisfaction ratings and attendance rates, and the fact that all participants indicated that they would recommend the READY Program to others with diabetes.

There was a significant increase in average daily step counts following the intervention (mean difference 3366 steps/day) and a significant decrease in sitting time (mean difference -137 mins/day) and a suggested positive trend in self-reported physical activity. This may indicate that, while participants did not increase time spent in moderate-vigorous exercise, they may have increased light intensity activities, such as slow walking. These results are particularly important not just for resilience and wellbeing outcomes, but because physical activity is a key aspect of diabetes management (Craig et al, 2011; Colagiuri et al, 2009) and sedentary behaviour increases the risk of cardiovascular and all-cause mortality (Dunstan et al, 2010). Bradshaw et al. (2007) also showed improvement in physical activity following diabetes resilience training that focussed on diabetes self-management. As the *READY* program included only one session on physical activity and did not focus on diabetes self-management, the physical activity improvements are promising. An earlier application of the ACT components of the READY Program with people with cancer also showed improvements in physical activity (Hawkes et al, 2013). Other research has demonstrated positive associations between mindfulness and physical activity (Roberts & Danoff, 2010; Ulmer, Stetson, & Salmon, 2010), and suggested that mindfulness may improve intrinsic motivation for (Ruffault et al, 2016), and mediate satisfaction with (Tsafou et al, 2016), physical activity.

In comparison to other published diabetes resilience training programs, the 20 hours of contact time for the READY Program was the same as that in Steinhardt et al.'s (2009) program, which demonstrated improvements on measures of diabetes empowerment and self-management, but not resilience, perceived stress or coping. The READY contact time was more than the 15 hours (over 5 weeks) in the Bradshaw et al. (2007) program, which demonstrated improvements in coping with diabetes-related stress, self-awareness, diabetes self-management, healthy eating, and physical activity at three-month follow-up. Both these programs included a focus on diabetes specific information (e.g., healthy eating, self-management), which was not part of the READY Program. Interestingly, a third or more of the READY participants described an improved ability and increased motivation to manage their diabetes effectively. There was also a marked reduction in diabetes-related distress and stress and a significant increase in physical activity, all of which contribute to better diabetes self-management.

It is important to note that the core READY Program content has not been changed in its application across a variety of chronic illnesses (e.g., cancer, diabetes, multiple sclerosis and congenital heart disease). It has been proposed that the ACT processes, along with other CBT strategies, represent generic therapeutic processes that target fundamental psychopathology processes (Hayes & Hoffman, 2017). Notably, in the present study the ACT processes were reported by most participants as particularly helpful.

Limitations of the study include the non-random sampling and an over-representation of females, which limits the generalisability of findings. As this study was a not a randomised controlled trial, we are unable to make conclusions about the efficacy of the program. In the absence of a follow-up assessment, we are unable to comment on the sustainability of these improvements. Further, there was a large number of outcome measures, which is important for the pilot examination of appropriate outcome scales to be included in future clinical trials of READY for diabetes, nevertheless this also increased the risk of Type II error. However, a more conservative significance level (p<.01) was used to protect against Type II error. Finally, it is unknown if participants had previously worn a pedometer, and if this alone may have accounted for increased steps. Given that the reactivity of pedometers appears to be transient and brief, and that the steps assessment was conducted post-intervention, it is unlikely to adequately explain the physical activity findings in the present study (Clemes & Deans, 2012).

Future research should examine the efficacy of the program in a controlled trial, the sustainability of intervention effects over the longer term, the mechanisms of change, and further refine the most appropriate outcome measures. Given participant feedback on suggested program enhancements, future applications of READY could examine the inclusion of diabetes-specific education, shorter program length, the use of online material to supplement the group intervention and delivery of the entire program online.

Findings suggest that it is feasible to implement READY as a group training program in community settings to promote resilience, emotional wellbeing and resilience protective factors in people with diabetes. Data supported the feasibility and acceptability of the READY Program for people with diabetes. Enhancing mental health and decreasing distress is especially important for this population, given the role that psychosocial variables have in shaping medical outcomes. Fostering resilience, psychological flexibility, positive affect, valued living, mindfulness and physical activity in people with diabetes is likely to enhance their coping with diabetes-related stress which, in turn, is likely to improve their lived experience of this chronic condition and reduce treatment burden and the use of medical services. Resilience training interventions, particularly those that include the core ACT processes, would be useful adjuncts to standard diabetes medical care and self-management programs.

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Table 1

Summary of READY Program Content

Content	Time allocated (mins)
Session 1 Introduction to READY	
• Orientation to program (including ground rules and rapport building)	25
• Outline of the *READY* Program and the *READY* Personal Plan	25
• Introduction to *READY* resources	
• Psycho-education on resilience and related protective factors	25
• Discussion and exercises to identify early warning signs of low resilience	25
• Review of key learnings	10
• Between session *READY* Personal Plan tasks presented	10
Session 2 Mindfulness	
• Review of previous session and *READY* Personal Plan activities	10
• Review of the *READY* resilience model	10

Content	Time allocated (mins)
• Introduction to mindfulness	10
• Psycho-education on mindfulness	15
• Practice of mindfulness exercises	45
• Individual reflection	15
• Review of key learnings	10
• Between session *READY* Personal Plan tasks presented	5
Session 3 Acceptance	
• Review of previous session and *READY* Personal Plan activities	10
• Mindfulness exercise	5
• Review of the *READY* resilience model	10
• Psycho-education on emotions and experiential avoidance	30
• Psycho-education on acceptance	10
• Acceptance experiential exercises	40

Content	Time allocated (mins)
• Review of key learnings	10
• Between session *READY* Personal Plan tasks presented	5
Session 4 Defusion	
• Review of previous session and *READY* Personal Plan activities	10
• Mindfulness exercise	5
• Review of the *READY* resilience model	5
• Psycho-education on thoughts and thought fusion	20
• Practise in identifying unhelpful thoughts	20
• Psycho-education on defusion	10
• Practise of defusion strategies	40
• Review of key learning	5
• Between session *READY* Personal Plan tasks presented	5
Session 5 Defusion and Observer Self	

Content	Time allocated (mins)
• Review of previous session and *READY* Personal Plan activities	10
• Review of the *READY* resilience model	5
• Mindfulness exercise	5
• Trouble shooting defusion strategies	20
• Practise of additional defusion techniques	35
• Observer-self metaphors and experiential exercises	30
• Review of key learnings	10
• Between session *READY* Personal Plan tasks presented	5
Session 6 Physical Activity	
• Review of previous session and *READY* Personal Plan activities	10
• Brief mid-program review	15
• Psycho-education on the benefits of physical activity for resilience	10
• Psycho-education on physical activity	15

Content	Time allocated (mins)
• Psycho-education on daily step counts, pedometer use, and ways to increase step counts	10
• Physical activity planning	30
• Physical activity problem solving	20
• Review of key learnings	5
• Between session *READY* Personal Plan tasks presented	5
Session 7 Values and Meaningful Action	
• Review of previous session and *READY* Personal Plan activities	10
• Review of the *READY* resilience model	10
• Psycho-education on values	30
• Values identification and connection	25
• Development of a values statement and related goals	25
• Review of key learnings	10

Content	Time allocated (mins)
• Between session *READY* Personal Plan tasks presented	10
Session 8 Pleasurable Activities	
• Review of previous session and *READY* Personal Plan activities	10
• Review of the *READY* resilience model	10
• Psycho-education on relaxation and resilience	10
• Practise of relaxation exercises	45
• Psycho-education on pleasurable activities	15
• Review of key learnings	10
• Between session *READY* Personal Plan tasks presented	10
Session 9 Review and Future Planning*	
• Review of previous session and *READY* Personal Plan activities	10
• Mindfulness exercise	5

Content	Time allocated (mins)
• Review *READY* resilience model	20
• Review resilience building strategies	25
Session 10 Review*	
• Review of key learnings	10
• Review *READY* Personal Plan	40
• Complete post-assessment	10
• End	

* = sessions were 60 minutes

Table 2.

Pre- to Post-intervention Changes in Resilience, Distress and Resilience Protective Factors (N = 20)

			t-test			*95% CI*	
	M(SD) Pre-intervention	M(SD) Post-intervention	*t* [a]	*r*	r^2	Lower Bound	Upper Bound
Resilience	67.65 (14.70)	75.90 (15.52)	3.00**	.67	.45	-14.00	-2.50
Distress:							
Diabetes-related distress	38.88 (23.20)	28.75 (19.80)	-0.57*	-.38	.14	.65	19.60
Depression	17.00 (12.32)	9.70 (10.57)	-3.57**	.36	.13	3.02	11.57
Anxiety	9.40 (10.74)	6.20 (8.41)	-2.19*	.36	.13	.14	6.36
Stress	19.20 (11.51)	11.80 (9.86)	-3.26**	.39	.15	2.65	12.15
Resilience Protective Factors:							

Positive affect	26.75 (9.30)	32.45 (9.77)	.57**	-.39	.15	-9.84	-1.55
Mindfulness	52.55 (11.82)	58.85 (12.18)	0.51*	-.37	.14	-11.89	-.71
Psychological flexibility	41.55 (8.88)	47.90 (8.75)	.65**	-.49	.24	-9.81	-2.89
Valued Living	234.78 (96.31)	285.28 (79.68)	.56**	-.39	.15	-89.86	-11.14
Physical Activity:							
Self-reported time (weighted mins/week)	136.45 (114.03)	155.00 (112.62)	.36	.17	.03	-78.59	55.59
Step Count (mean steps/day)	4,732.18 (2339.39)	8,098.24 (3,453.64)	6.44**	.51	.26	-4474.77	-2257.35
Self-reported sitting Time (mins/day)	607.25 (245.39)	470.25 (159.76)	-.68**	-.52	.27	-52.40	-221.40

[a] *df* = 19. * p <.05. ** p <.01.

Model Reactions Involving Ester Functional Groups During Thermo-oxidative Degradation of Biodiesel

Running Title: Ester group reactions in biodiesel oxidation.

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Abstract

Biodiesel is a renewable fuel used in diesel engines that is typically blended with diesel fuel. However, biodiesel is susceptible to oxidation, which has the potential to produce higher molecular weight materials that may adversely impact vehicle fuel-system performance. To investigate the chemical reactions potentially important in biodiesel oxidation, four different types of chemical reaction involving esters were studied: 1) ester formation (reactions of acids with alcohols), 2) alcoholysis (reactions of alcohols with esters), 3) acidolysis (reaction of acids with esters), and 4) ester exchange (reactions between two esters). Experiments with representative model compounds were used to evaluate these reactions at 90 °C with aeration; conditions previously used to simulate thermo-oxidative degradation during biodiesel aging. Reactions were monitored using gas chromatography, FTIR spectroscopy, and total acid number

(TAN). Evidence is presented suggesting that alcoholysis and ester formation (reactions 1 and 2), catalyzed by carboxylic acids, are important reactions of esters that could lead to larger molecules. Acidolysis (reaction 3) proceeded at a comparatively slow rate and ester exchange reaction products (reaction 4) were not detected under these aging conditions.

Key Words: Ester Group, Reactions of Esters, Biodiesel Oxidation, Model Reactions

Introduction

Biodiesel is a renewable fuel for compression ignition (diesel) engines that is typically blended with petroleum diesel at concentrations up to 20% by volume. Biodiesel production involves the chemical conversion of plant oils and animal fats (triacylglycerides of typically C16-C18 fatty acids) into individual fatty acid methyl esters (FAMEs), which reduces viscosity and improves cold temperature performance. While the cetane number, lubricity, and soot-forming tendency of biodiesel is attractive relative to petroleum diesel (Knothe, G., Van Gerpen, J. H. & Krahl, J. 2005), biodiesel is susceptible to oxidation with potentially adverse impacts on fuel quality and engine and fuel system performance (Knothe, G., Van Gerpen, J. H. & Krahl, J. 2005; Waynick, J. A. 2005).

Biodiesel includes FAMEs of both saturated and unsaturated fatty acids. Oxidation susceptibility is closely related to the content of polyunsaturated FAMEs and secondarily to monounsaturated FAMEs. Oxidation reactions are initiated by reactive oxygen species at carbon atoms adjacent (allylic) to double-bonded carbon atoms (Knothe, G., Van Gerpen, J. H. & Krahl, J. 2005; Waynick, J. A. 2005). A sequence of radical reactions including hydrogen abstraction, molecular oxygen addition, and intramolecular isomerization leads to a range of oxygenated products with a variety of functional groups. Higher molecular weight materials formed in these reactions increase the viscosity of the fuel and can lead to deposits in the engine (Fang, H. L. & Mccormick, R. L. 2006). The reaction pathways and rates vary with temperature (Waynick, J. A. 2005).

In earlier papers, we monitored biodiesel oxidation at 90 °C with aeration, characterized the impact of the resulting thermo-oxidative degradation on fuel composition and properties, and subsequently chemically characterized the resulting higher molecular weight products (Ball, J. C., Anderson, J. E., Pivesso, B. P. & Wallington, T. J. 2018; Ball, J. C., Anderson, J. E. & Wallington, T. J. 2018; Østerstrøm, F. F., Anderson, J. E., Mueller, S. A., Collings, T., Ball, J. C. & Wallington, T. J. 2016). These experiments confirmed that compounds with new ester linkages (polyester polymers) were significant contributors to the high molecular weight products and the increased viscosity. Saturated FAMEs (methyl stearate and methyl palmitate), which do not contain double bonds, were observed to oxidize to a limited extent (Østerstrøm, F. F., Anderson, J. E., Mueller, S. A., Collings, T., Ball, J. C. & Wallington, T. J. 2016) even though saturated FAMEs are generally thought to be considerably less reactive under these conditions (Knothe, G., Van Gerpen, J. H. & Krahl, J. 2005; Waynick, J. A. 2005).

Four different chemical reactions involving ester functional groups are noted in the literature (Barkenbus, C., Roswell, C. A. & Mitts, A. E. 1940; Formo, M. W. 1954; Koskikallio, J. 1969; Wright, H. J., Segur, J. B., Clark, H. V., Coburn, S. K., Langdon, E. E. & Dupuis, R. N. 1944):

1) ester formation (reactions of carboxylic acids with alcohols),

2) alcoholysis (reactions of alcohols with esters),

3) acidolysis (reactions of carboxylic acids with esters), and

4) ester exchange (reactions between two esters).

However, the potential involvement and relevance of these reactions have not been investigated for the oxidizing conditions found in diesel fuel systems (elevated temperature and aeration). To address this, a series of experiments were conducted to explore the significance of these reactions under such conditions using model compounds representative of biodiesel and biodiesel oxidation products.

Experimental Procedures

Soybean methyl ester (SME) biodiesel without added antioxidants was obtained from Gage Products (Ferndale, MI). The biodiesel fuel was oxidized by heating in glass tubes at 90 °C while aerating with100 mL/min dry air as described previously (Ball, J. C., Anderson, J. E., Pivesso, B. P. & Wallington, T. J. 2018; Ball, J. C., Anderson, J. E. & Wallington, T. J. 2018; Østerstrøm, F. F., Anderson, J. E., Mueller, S. A., Collings, T., Ball, J. C. & Wallington, T. J. 2016). Sample tubes were covered by glass condenser caps fed with 20 °C chilled water to reduce evaporative losses. Properties of the SME biodiesel are shown in Table S1 of Supporting Information. Individual FAMEs, alcohols, and reagents were obtained from commercial sources (Fischer Scientific, Pittsburgh, PA).

Decyl decanoate was prepared by reacting decanoyl chloride with a 10% molar excess of decanol at 100 °C for 12 hours followed by vacuum distillation to remove unreacted material. The decyl decanoate product was verified by FTIR spectroscopy against a reference spectrum

(Sdbsweb 2018). Hexadecyl stearate was prepared by reacting an equimolar concentration of hexadecanol with stearoyl chloride and heating at 80 °C for two hours. This product was used without further purification to identify the GC-FID peak elution time of hexadecyl stearate.

Decanol, decyl decanoate, and other esters were quantified using gas chromatography with flame ionization detection (GC-FID). The GC was equipped with a Restek Rxi-5HT column (30 m x 0.320 µm x 0.25 µm) and used with the following parameters: inlet temperature 380 °C; initial temperature 110 °C, held for 1 minute, 5.0 °C/min ramp to 390 °C, and held at 390 °C for 15 minutes; 1 mL/min He carrier gas flow; 20:1 split ratio; 1.0 µL injection volume. Samples were diluted in dichloromethane prior to injection.

Experiments using model compounds were conducted using the same experimental conditions used in previous biodiesel aging studies (90°C with 100 mL/min dry air) (Ball, J. C., Anderson, J. E., Pivesso, B. P. & Wallington, T. J. 2018; Ball, J. C., Anderson, J. E. & Wallington, T. J. 2018; Østerstrøm, F. F., Anderson, J. E., Mueller, S. A., Collings, T., Ball, J. C. & Wallington, T. J. 2016). Ester formation was evaluated by studying the reaction of decanol and decanoic acid. Alcoholysis of esters was evaluated by studying the reaction of hexadecanol and methyl stearate at equimolar concentrations, and again with hexadecanol, methyl stearate, and methyl linoleate at a 1.0:1.0:0.2 molar ratio. Acidolysis of esters was evaluated by studying the reaction of methyl palmitate and stearic acid at equimolar concentrations. Ester exchange reactions were evaluated by studying the reaction of ethyl palmitate and methyl stearate at equimolar concentrations. Model compounds and their boiling points are provided in Table 1. Vapor pressures are available in Table S2. The progress of the reactions was generally monitored by quantifying product and reactant concentrations by GC-FID. Decanoic acid was quantified using FTIR spectroscopy with attenuated total reflectance at 1670 cm^{-1} using a Thermo Scientific Nicolet iS 10 spectrometer equipped with a Smart ARK accessory. TAN was determined by titration with 0.5 N KOH using AOCS Method Cd 3d-63 (Sallee, E., Hopper, T., Link, W., Walker, R., Firestone, D. & Mehlenbacher, V. 2004).

Results & Discussion

In our previous studies of biodiesel oxidation, saturated FAMEs were observed to be slowly, but steadily, oxidizing during experiments at elevated temperature (90 °C with aeration) (Ball, J. C., Anderson, J. E., Pivesso, B. P. & Wallington, T. J. 2018; Østerstrøm, F. F., Anderson, J. E., Mueller, S. A., Collings, T., Ball, J. C. & Wallington, T. J. 2016). An example for 100% soybean biodiesel oxidation is shown in Figure 1. Polyunsaturated FAMEs (methyl linolenate, C18:3, and methyl linolenate, C18:2) oxidized quickly while monounsaturated methyl oleate (C18:1) oxidized more slowly, as expected. However, the concentrations of the two saturated FAMEs (methyl stearate, C18:0, and methyl palmitate, C16:0) also declined, albeit very slowly, which was not expected. Chemical or physical mechanisms leading to their removal were not characterized, but it was hypothesized that saturated esters might undergo oxidation reactions on the alkyl chain via thermal degradation or attack by free radicals generated from oxidation of the unsaturated FAMEs.

Three reactions were identified that could have contributed to FAME removal and potentially to formation of larger molecules leading to increased viscosity: alcoholysis (reaction of an alcohol with an ester), acidolysis (reaction of an acid with an ester), and ester exchange (reactions between two esters) (Barkenbus, C., Roswell, C. A. & Mitts, A. E. 1940; Formo, M.

W. 1954; Koskikallio, J. 1969; Wright, H. J., Segur, J. B., Clark, H. V., Coburn, S. K., Langdon, E. E. & Dupuis, R. N. 1944). These reactions and ester formation by reaction of acids with alcohols were investigated through experiments using model compounds. The commercially-available model compounds chosen were intended to 1) be representative of biodiesel and biodiesel oxidation products (C10-C18 fatty acids, esters, and alcohols), 2) have sufficiently low vapor pressure to be adequately retained in the experimental system, and 3) have products with boiling points sufficiently low to be measured by GC (Table 1). Each of these reactions could potentially be driven to product formation if one of the products was of sufficiently low molecular weight that it would be stripped from solution as it formed. For example, acetic acid, methyl butyrate, and methanol have vapor pressures similar to or greater than water (40, 68, and 255 kPa, respectively, vs. 70 kPa for water) at 90 °C; water is readily stripped in these experiments.

Ester Formation

Ester formation during the thermo-oxidative degradation of SME biodiesel was indicated previously through several lines of evidence, including an overall increase in ester content (Ball, J. C., Anderson, J. E., Pivesso, B. P. & Wallington, T. J. 2018). In our previous study, ester formation from alcohol and acid oxidation products were proposed to explain the observation that ester content steadily increased and comprised 40–60% of the incorporated oxygen for biodiesel-containing fuels aged under these conditions. The ester products were hypothesized to form from reaction of carboxylic acids and alcohols, both of which are known biodiesel oxidation products (Chuck, C. J., Bannister, C. D., Jenkins, R. W., Lowe, J. P. & Davidson, M.

G. 2012; Waynick, J. A. 2005; Wexler, H. 1964). The formation of carboxylic acids is likely due to the oxidation of aldehydes and ketones that are present as secondary degradation products from the oxidation of the FAMEs. Alcohols are likely generated through hydrogen abstraction from alkoxy radicals during FAME oxidation. Carboxylic acids and alcohols form esters and water in a reversible equilibrium reaction (Morrison, R. T. & Boyd, R. N. 1992). The aging conditions (90 °C with aeration) continuously remove water which drives the equilibrium toward ester formation. The example in Reaction 1 shows compounds with both alcohol and carboxylic acid functional groups (hydroxycarboxylic acid) being linked by a new ester bond. The product is another hydroxycarboxylic acid that could continue to react to generate a larger polyester. The hydroxycarboxylic acid would likely be formed from an alkoxy carboxylic acid formed during the oxidation of a FAME. The alkoxy radical would abstract a hydrogen from another hydrocarbon or water to generate a hydroxycarboxylic acid. Such polyfunctional compounds (e.g., dicarboxylic acids, dialcohols, and hydroxycarboxylic acids) could act as cross-linking reactants. Dicarboxylic acids have been detected as products of biodiesel oxidation and from depolymerization of higher molecular weight oxidation products under the thermo-oxidative aging conditions used in the present study (Ball, J. C., Anderson, J. E. & Wallington, T. J. 2018; De Carvalho, A. L., Cardoso, E. A., Da Rocha, G. O., Teixeira, L. S. G., Pepe, I. M. & Grosjean, D. M. 2016; Wexler, H. 1964).

To test the underlying hypothesis that long-chain carboxylic acids and alcohols could have reacted to generate new esters in the prior biodiesel aging studies (Ball, J. C., Anderson, J. E., Pivesso, B. P. & Wallington, T. J. 2018; Ball, J. C., Anderson, J. E. & Wallington, T. J. 2018), an experiment was conducted allowing decanol and decanoic acid (each at 50 mol %

concentration) to react under the same conditions (90 °C, 100 mL/min dry air). The expected ester product, decyl decanoate, was formed rapidly in the expected stoichiometric amount as the two reactants disappeared (Figure 2). The slightly greater removal of decanol relative to decanoic acid, despite a 1:1 stoichiometric reaction and equimolar initial concentrations, may be due to volatile loss of decanol. The boiling point of decanol is considerably lower than that of decanoic acid (Table 1) and its vapor pressure is correspondingly higher (Table S2). As such, decanol is susceptible to volatile losses due to continuous aeration, though mitigated by the presence of a water-cooled chiller. The relatively short time scale in which this ester-forming reaction occurred (2 days for 50% reaction) demonstrates that esters could be formed from alcohols and carboxylic acids generated during the biodiesel aging studies, which were up to 43 days in duration.

Alcoholysis

Alcoholysis involves the equilibrium reaction of an alcohol with an ester to form a product alcohol and a product ester, i.e., replacing the alcohol group in the ester reactant with a different alcohol. Alcohols could be present as products of biodiesel oxidation. Higher molecular weight alcohols have also been studied as oxygenated diesel-range fuel components (Muinos, M., Soloiu, V., Moncada, J., Gaubert, R., Molina, G. & Williams, J. 2017). The addition of acid (e.g. methanolic HCl) or base (e.g. sodium methoxide in methanol) catalysts in the alcoholysis of triacylglycerides to produce biodiesel fuels is well known. The possibility that alcoholysis, in the absence of added acid or base catalysts, could occur between a FAME and an alcohol product of FAME oxidation has been proposed (Formo, M. W. 1954). A hypothetical example is given in Reaction 2, showing a biodiesel FAME reacting with the alcohol functional group of another molecule to form a larger molecule and methanol.

To test the hypothesis that alcoholysis reactions can occur with biodiesel under the aforementioned aging conditions, experiments were conducted allowing hexadecanol and methyl stearate (at equal molar concentrations) to react under the same conditions. These two reactants were chosen because they give products that can be assigned unambiguously to alcoholysis and esterification reactions. Figure 3 (black symbols) shows details of the reaction of hexadecanol with methyl stearate. In this experiment, a slow formation of hexadecyl stearate was observed over 45 days (Figure 3, top panel). The products of the alcoholysis reaction are hexadecyl stearate and methanol. Under these conditions (90 °C, aeration) methanol would be quickly stripped from solution, driving the equilibrium reaction toward the hexadecyl stearate product.

In this experiment, hexadecyl palmitate formation was also observed (Figure 3, top panel), albeit at a much slower rate (about <1% of hexadecyl stearate formation). This additional product is attributed to the esterification reaction of hexadecanol with palmitic acid (hexadecanoic acid), the latter presumably formed from hexadecanol oxidation under these conditions. Over the first 45 days, TAN (Figure 3, lower panel) remained at very low levels (~0.25 mg KOH/g) relative to oxidation experiments with biodiesel (typically ~30 mg KOH/g). The difference is due to the lack of polyunsaturated FAMEs (which are much more reactive than methyl stearate) and possibly because any acids produced could quickly react with hexadecanol.

At day 45 of the same experiment (Figure 3, top panel), palmitic acid (13 mol %) was intentionally added, resulting in more rapid production of hexadecyl stearate (alcoholysis), indicating that palmitic acid and presumably other carboxylic acids can catalyze the alcoholysis reaction. Hexadecyl palmitate was simultaneously produced via esterification of the added palmitic acid with hexadecanol. Because both reactions involve hexadecanol, the experiment was terminated when hexadecanol was fully consumed. While the acid-catalyzed alcoholysis reaction proceeded faster than esterification, their rates cannot be directly compared because palmitic acid was present at lower concentration than methyl stearate.

Immediately after the palmitic acid was added on day 45 (with TAN increasing correspondingly), TAN dropped due to esterification of the palmitic acid with hexadecanol (Figure 3, lower panel). After 7 days (day 52 overall), TAN started increasing suggesting that thermo-oxidative degradation reactions had initiated (presumably of hydrocarbon chains).

These results may help explain preliminary alcoholysis experiments (data not shown) in which the alcoholysis product was formed rapidly, but only after a lag time of 14-21 days. Despite some variability in lag time between replicates, the onset of alcoholysis coincided with the onset of rapid TAN formation. Carboxylic acids can be formed from the oxidation of the aliphatic side chains of the reactants, although the rate is certainly slower than at allylic reactive sites in unsaturated FAMEs (Chuck, C. J., Bannister, C. D., Jenkins, R. W., Lowe, J. P. & Davidson, M. G. 2012; De Carvalho, A. L., Cardoso, E. A., Da Rocha, G. O., Teixeira, L. S. G., Pepe, I. M. & Grosjean, D. M. 2016; Waynick, J. A. 2005). The dramatic increase in the formation of the alcoholysis product coinciding with rapid TAN formation is consistent with carboxylic acids acting as an in-situ catalyst in the alcoholysis reaction. This set of experiments suggests that alcoholysis, especially in the presence of newly generated carboxylic acids, is a viable reaction of methyl esters with alcohols formed during the thermo-oxidative degradation of biodiesel fuel.

To further test the hypothesis that FAME oxidation products (e.g., carboxylic acids) can catalyze the alcoholysis reaction in this experiment, the hexadecanol/methyl stearate experiment was repeated while adding methyl linoleate (9 mol %) at the start of the experiment (Figure 3, red symbols). Methyl linoleate, the most abundant FAME in SME biodiesel, oxidizes more rapidly than saturated FAMEs and was depleted to only 10% of the initial concentration after 3 days. As seen in Figure 3, the presence and presumed thermo-oxidative degradation of the methyl linoleate led to more rapid formation of both hexadecyl stearate and hexadecyl palmitate than without methyl linoleate. TAN (Figure 3, lower panel) rapidly increased with essentially no lag time, whereas the alcoholysis and esterification products started forming after a much shorter lag time (3 days) than without methyl linoleate. The rate of hexadecyl stearate formation (alcoholysis) was similar to that with palmitic acid added. In contrast, hexadecyl palmitate formation (esterification) was considerably slower than with added palmitic acid. In the absence of any added palmitic acid, palmitic acid would have only been generated from the oxidation of hexadecanol.

The relationship between the formation of acids and the product of the alcoholysis reaction was explored by plotting the formation of hexadecyl stearate versus TAN. As seen in Figure 4, the dependence of the observed formation of hexadecyl stearate on TAN can be accounted using a sigmoidal model function. A sigmoidal function was chosen as a model for this reaction because the products would form slowly at first when the concentration of carboxylic acids are low, the rate would increase as more carboxylic acids were generated and the rate would slow due to consumption of reactants. A similar plot was not generated for the reaction of hexadecanol and methyl stearate because of the long lag time needed for acid formation and the subsequent addition of palmitic acid. These data (Figure 4) give additional support for the hypothesis that carboxylic acids act as catalysts in the alcoholysis reactions. Together, these experiments demonstrate that alcohols and carboxylic acids, formed from the thermo-oxidative degradation of biodiesel fuel, can react to form new esters (Figures 2 and 3). In addition, alcohols can react with methyl esters to form different esters that will be larger than methyl esters (Figures 3 and 4).

Carboxylic acids, formed in-situ from the oxidation of biodiesel, have been reported to act as a catalyst in the alcoholysis reaction (Otton, J. & Ratton, S. 1988; Salmi, T., Paatero, E. & Nyholm, P. 2004). Otton and Ratton suggested that carboxylic acids act as a catalyst in both esterification and alcoholysis reactions (Otton, J. & Ratton, S. 1988). Their work monitored the reactions of model alcohols (e.g., heptanol), esters (e.g., heptyl benzoate), and a carboxyl acid (benzoic acid) at temperatures greater than 150 °C in a large excess of the alcohol (Otton, J. & Ratton, S. 1988). Their data suggest that the alcoholysis reaction does not occur except in the presence of a carboxylic acid. Otton and Ratton reported that the rate of ester formation reactions was 2-3 times greater than the rate of alcoholysis reactions at equimolar concentrations of the reactants (Otton, J. & Ratton, S. 1988). Despite this, the reaction of alcohols with FAMEs may also be important because FAMEs would generally be present at much higher concentration than the acid oxidation products. For example, SME biodiesel aged under these conditions eventually yielded a TAN of 30 mg KOH/g (Ball, J. C., Anderson, J. E., Pivesso, B. P. & Wallington, T. J. 2018), which assuming the carboxylic acid molecular weight approximates that of decanoic acid, gives a 6:1 concentration ratio of FAMEs to carboxylic acids. Both reactions are driven by volatilization of one of the products; the alcoholysis reaction with FAMEs produces methanol, while esterification of acids and alcohols formed from biodiesel oxidation generate water. These results suggest that alcoholysis of methyl esters to form new esters are likely to be a significant reaction for alcohols formed during the thermo-oxidative degradation of biodiesel.

Acidolysis

Acidolysis of an ester is the equilibrium reaction of a carboxylic acid and an ester to form a different ester and carboxylic acid (i.e., replacing the carboxylic acid group in the ester reactant with another carboxylic acid; Reaction 3). To investigate whether acidolysis could occur at relevant rates under these aging conditions, stearic acid and methyl palmitate (at equal molar concentrations) were allowed to react, with the expected products being methyl stearate and palmitic acid. Over 35 days, small amounts of both products were observed, with product concentrations reaching approximately 1-2% of the reactant concentrations (Table 2) despite the high concentration of stearic acid (50 mole %). Whereas the equilibrium reaction of these model compounds was not driven towards product formation as neither of the products are significantly volatile, the reaction might be driven in other cases if one product was sufficiently volatile (e.g., acetic acid or methyl butyrate). These data suggest that acidolysis reactions may be occurring in the aforementioned biodiesel aging studies but likely at a relatively slow rate compared to direct ester formation and alcoholysis. Otton and Ratton, using p-toluic acid and heptyl benzoate, found that the rate of acidolysis was about 10% of the rate of ester formation between the corresponding alcohol and carboxylic acid (Otton, J. & Ratton, S. 1988). While carboxylic acids are reactants in acidolysis, it is not known if they also catalyze this reaction.

Ester Exchange

Ester exchange reactions are another class of equilibrium reactions that potentially occur between two esters to form two different esters, (i.e., exchanging the two alcohol groups, or equivalently the two carboxylic acid groups, between the two ester reactants; Reaction 4). This reaction would result in no identifiable change in composition for the initial biodiesel FAME mixture (it would exchange methanol for methanol). However, ester exchange reactions could result in composition changes after thermo-oxidative degradation of the FAME mixture generates a variety of esters with different alcohol and acid components.

The relevance of this reaction under the aging study conditions was evaluated by allowing two model ester compounds, ethyl palmitate and methyl stearate (at equal molar concentrations), to react, with the expected exchange products being ethyl stearate and methyl palmitate. After a 35-day reaction period, no evidence of the expected products was detected by GC-FID (Table 3), suggesting that ester exchange reactions (between FAMEs and/or other esters) are not likely to be a significant reaction under the aging conditions used here. For the reaction of these model compounds, the equilibrium reaction was not driven towards product formation as neither of the products are significantly volatile. The reaction might be driven in other cases if one of the product esters was sufficiently volatile (e.g., methyl butyrate). While catalysis by acids was not explicitly investigated, no ester exchange was observed despite significant amounts of acids being generated during the 35-day reaction period (Table 3).

Oxidation Reactions

While not involving the ester functional group, oxidation of the hydrocarbon chain in FAMEs occurs and contributes to the reactions involving the ester functional groups. Oxidation is relatively rapid for unsaturated FAMEs and the resulting products are both reactants and in some cases catalysts for alcoholysis, ester formation, and acidolysis reactions.

Saturated FAMEs may also be susceptible to thermo-oxidative degradation, albeit slowly and/or with an extended lag time, in these ester-focused experiments. To investigate this further, methyl stearate was allowed to oxidize under the same aging conditions as in the other experiments (Figure 5). As in the alcoholysis experiments, there was a lag time before evidence of significant oxidation was observed in the form of increasing TAN. After 42 days, the TAN reached ~60 mg KOH/g and approximately half of the methyl stearate appeared to have reacted, with numerous product peaks detected by GC-FID. The existence of a lag time suggests that these thermo-oxidative degradation reactions involve chain reactions involving oxidation products.

Conclusions

Four reactions involving ester functional groups (as reactants and/or products) were investigated that are relevant in biodiesel thermo-oxidative degradation studies. These reactions could involve biodiesel FAMEs and their oxidation products as reactants, and could play roles in determining the resulting products that are formed, including high molecular weight polyesters. These reactions were experimentally evaluated using model compounds under conditions of prior biodiesel thermo-oxidative degradation studies (90 °C with aeration) (Ball, J. C., Anderson, J. E., Pivesso, B. P. & Wallington, T. J. 2018; Østerstrøm, F. F., Anderson, J. E., Mueller, S. A., Collings, T., Ball, J. C. & Wallington, T. J. 2016).

Of the four ester reactions, ester formation from alcohols and acids (known biodiesel oxidation products) occurred at the highest rate. The alcoholysis reaction, involving replacement of one alcohol for another within an existing ester, occurred at a somewhat slower rate and was only observed in the presence of carboxylic acids (either directly added or after significant oxidation and TAN formation had occurred), consistent with catalysis by carboxylic acids (Otton, J. & Ratton, S. 1988). The formation of new esters is consistent with prior biodiesel oxidation studies (Otton, J. & Ratton, S. 1988). Both ester formation and alcoholysis were driven by stripping of a volatile product (water or methanol, respectively). Acidolysis was observed to occur, but at a much slower rate than ester formation and carboxylic acid-catalyzed alcoholysis (Otton, J. & Ratton, S. 1988). Ester exchange reactions were not observed with the model compounds.

Together, these experiments suggest a set of complex inter-related reactions originating from FAMEs and their thermo-oxidative degradation products that can contribute to the formation of new esters with potentially higher molecular weight and therefore leading to increased viscosity. Carboxylic acids and alcohols, known biodiesel oxidation products, played critical roles in many aspects of these reactions. Alcohols and carboxylic acids, formed from the oxidation of biodiesel fuel, can react to form new esters. Alcohols can also react with methyl esters to form different esters. The alcohol functional group can also oxidize to a carboxylic acid. Ester formation and alcoholysis reactions are catalyzed by the carboxylic acids generated from FAME oxidation (with unsaturated FAMEs being most reactive) and alcohol oxidation. Based on these results, alcoholysis and esterification are now believed to have been the most prevalent of the three alcohol reactions in our prior biodiesel aging studies (Ball, J. C., Anderson, J. E., Pivesso, B. P. & Wallington, T. J. 2018; Østerstrøm, F. F., Anderson, J. E., Mueller, S. A., Collings, T., Ball, J. C. & Wallington, T. J. 2016) due to the relative abundance of available esters and acids.

The fact that alcohols are not found in large amounts as oxidation products in biodiesel oxidation studies may be due to the titration of alcohols by esterification reactions and alcoholysis reactions with methyl esters (forming methanol which may evaporate), as well as conversion to aldehydes and acids via oxidation reactions. Alcohols are likely to be the limiting reactant in these reactions, as carboxylic acids and esters are generally always present in relative abundance during these oxidation studies.

Saturated FAMEs, while understood to be considerably less reactive via oxidation as compared to unsaturated FAMEs, were shown to be susceptible to carboxylic acid-catalyzed alcoholysis and, to a lesser extent, acidolysis. Saturated FAMEs also appear to be susceptible to alkyl chain oxidation.

FAME thermo-oxidative degradation reactions and these ester-specific reactions, individually and collectively, have the potential to generate a diverse array of products. The ester reactions have the potential to generate larger molecules that increase viscosity, both from exchange of smaller groups for larger groups and from linkages by polyfunctional oxidation products (e.g., di-carboxylic acids, di-alcohols, and hydroxycarboxylic acids) to form polyesters.

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Tables

Table 1. Model reactants and products

Compound name	Common name	Reactant (R), Product (P)	CAS number	Formula	Boiling point[a] (ºC), 1 atm
water	water	P	7732-18-5	H_2O	100
methanol	methanol	P	67-56-1	CH_4O	65
n-decanol	decanol	R	112-30-1	$C_{10}H_{22}O$	230
n-decanoic acid	decanoic acid	R	334-48-5	$C_{10}H_{20}O_2$	270
n-hexadecanol	hexadecanol	R	36653-82-4	$C_{16}H_{34}O$	325
n-hexadecanoic acid	palmitic acid	P	57-10-3	$C_{16}H_{32}O_2$	350
n-hexadecanoic acid, methyl ester	methyl palmitate	R,P	112-39-0	$C_{17}H_{34}O_2$	325
n-hexadecanoic acid, ethyl ester	ethyl palmitate	R	628-97-7	$C_{18}H_{36}O_2$	242
n-octadecanoic acid	stearic acid	R	57-11-4	$C_{18}H_{36}O_2$	374
cis-9, cis-12-octadecadienoic acid, methyl ester	methyl linoleate	R	112-63-0	$C_{19}H_{34}O_2$	346
n-octadecanoic acid, methyl ester	methyl stearate	R,P	112-61-8	$C_{19}H_{38}O_2$	351
n-octadecanoic acid, ethyl ester	ethyl stearate	P	111-61-5	$C_{20}H_{40}O_2$	356
n-decanoic acid, n-decyl ester	decyl decanoate	P	1654-86-0	$C_{20}H_{40}O_2$	362[b]
n-hexadecanoic acid, n-hexadecyl ester	hexadecyl palmitate	P	540-10-3	$C_{32}H_{64}O_2$	534[b]
n-octadecanoic acid, n-hexadecyl ester	hexadecyl stearate	P	1190-63-2	$C_{34}H_{68}O_2$	528(est)[b]

[a.] Data from 2018 DIPPR® Evaluated Database©, unless otherwise noted, and published with permission of AIChE®

[b.] TGSC database (Last accessed October 4 2018)

Table 2. Acidolysis products from the reaction of stearic acid with methyl palmitate

Elapsed time (days)	Methyl stearate (% of initial methyl palmitate peak area)	Palmitic acid (% of initial stearic acid peak area)
0.08	0.34	0.05
1	0.42	0.06
2	0.37	0.06

3	0.37	0.05
35	1.10	2.3

Table 3. Ester exchange products from the reaction of methyl stearate and ethyl palmitate

Elapsed time (days)	Ethyl stearate (% of initial methyl stearate peak area)	Methyl palmitate (% of initial ethyl palmitate peak area)	TAN (mg KOH/g)
0.08	ND[a]	ND	1.1
7	ND	ND	1.1
14	ND	ND	1.9
21	ND	ND	9.9
28	ND	ND	19.3
35	ND	ND	33.4

[a] Not detected

Figure and Reaction Legends

Figure 1. Percent of initial FAME concentration for soybean biodiesel oxidized at 90 °C with aeration. Reprinted (adapted) with permission from Ball, J. C., Anderson, J. E., Pivesso, B. P., & Wallington, T. J. (2018) Oxidation and Polymerization of Soybean Biodiesel/Petroleum Diesel Blends. *Energy & Fuels,* **32**:441-449. Copyright (2018) American Chemical Society.

Reaction 1. Polymeric ester formation (reactions of carboxylic acids with alcohols)

Figure 2. Ester formation reaction of decanoic acid and decanol initially at equimolar concentrations, reacting to form decyl decanoate, at 90 ºC with aeration. Results for duplicate experiments are shown as open and filled symbols.

Reaction 2. Alcoholysis (reaction of alcohols with esters).

Figure 3. Alcoholysis reaction of hexadecanol with methyl stearate initially at equimolar concentrations, with (red symbols) and without (black symbols) 9 mole % methyl linoleate. Top: ester products, hexadecyl stearate (circles) and hexadecyl palmitate (squares). Bottom: TAN. Results for duplicate experiments are shown as open and filled symbols. Experiment conducted at 90 °C with aeration. Palmitic acid (13 mole %) was added at day 45. Experiments were terminated when hexadecanol was fully consumed.

Reaction 3. Acidolysis (reaction of carboxylic acids with esters).

Reaction 4. Ester exchange (reaction between two esters).

Figure 4. Hexadecyl stearate formation as a function of TAN from the reaction of hexadecanol and methyl stearate initially at equimolar concentrations and containing 9 mole % methyl linoleate. Experiment conducted at 90 °C with aeration over 16 days. Acids are initially formed from the oxidation of methyl linoleate. Results for duplicate experiments are shown as open and filled symbols. The line is the best fit to a sigmoidal curve ($r^2 = 0.98$). One outlier (open red circle) was not included in the fit of the data.

Figure 5. Oxidation of methyl stearate at 90 °C with aeration. Methyl stearate (black circles) and TAN (green squares) were measured for 42 days. Results for duplicate experiments are shown as open and filled symbols.

A pilot evaluation of a group acceptance and commitment therapy (ACT)-informed resilience training program for people with diabetes

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A Pilot Evaluation of a Group Acceptance and Commitment Therapy (ACT)-Informed Resilience Training Program for People with Diabetes

Abstract

Objective. Individuals with diabetes can experience poor mental health, which is associated with poor physical health outcomes. Few studies have examined interventions to increase resilience and related protective factors in people with diabetes. The purpose of this study was to undertake a pilot evaluation of an Acceptance and Commitment Therapy (ACT)-informed group resilience training program for people with diabetes. **Methods.** We delivered the program in community venues to 20 people with diabetes, with 10 x 2 hour weekly sessions. Assessment was conducted at pre- and post-intervention using questionnaires and pedometers. **Results.** There were significant improvements in resilience, psychological flexibility, positive affect, valued living, physical activity and sedentary behaviour, and significant decreases in depression and stress ($p<.01$). Improvements in mindfulness, diabetes-related distress and anxiety approached significance ($p<.05$). Feasibility and acceptance data showed high program engagement and satisfaction, and self-reported improvements that supported the statistically significant changes. **Conclusions.** ACT-informed resilience training is a promising means to strengthen resilience and related protective factors, and improve mental health in this population and warrants further evaluation in randomised controlled trials.

Keywords

acceptance and commitment therapy, diabetes, resilience, resilience training, quality of life

Key Points

What is already known about this topic

1. Most psychological interventions for people with diabetes have focused on reducing distress, rather than enhancing resilience and related protective factors.
2. Resilience has been identified as an important resource for people with diabetes.
3. Few published studies have evaluated resilience training for this population.

What this topic adds

1. This study evaluated the effectiveness and feasibility of an Acceptance and Commitment Therapy (ACT)-informed group resilience training program for people with diabetes.
2. Findings provide preliminary support for the utility of an ACT-informed group resilience training program for improving resilience, distress and a range of protective factors in people with diabetes.
3. ACT-informed resilience training delivered in the community was feasible, acceptable, and well received by these people with diabetes.

Diabetes is a chronic condition with a demanding treatment regime that places substantial psychological, physical, and social stress on the individual. The negative impacts of diabetes on functioning in many life domains is clearly established (Acchab et al, 2008). Work, social functioning, relationships, and emotional and physical wellbeing can be compromised, with high rates of depression and anxiety (Campayo et al, 2014; Holt, de Groot & Golden, 2014; Khuwaja et al, 2010; Smith et al, 2013; Svenningsson et al., 2011; Tan et al, 2015). Adults with diabetes have a higher prevalence (43%) of distress than those without diabetes (Australian Institute of Health and Welfare, 2011). This, in turn, adversely affects diabetes self-management and health outcomes and increases the burden of disease.

Most psychological interventions for people with diabetes have focused on reducing distress, rather than enhancing resilience and related protective factors, which are likely to provide long-term benefits (Pascoel et al, 2017). Resilience is the ability to 'bounce back' from, and successfully adapt to stressful life events, and involves a process of adaptation to stress or trauma that is influenced by an individual's internal and external resources (Windle, Bennett & Noyes, 2011). Resilience is an important predictor of quality of life (QoL) in people with physical disability and illness, and has been shown to ameliorate the adverse effects of fatigue and pain on QoL in a mixed disability sample (Terrill et al, 2016). A review identified five key resilience protective factors: positive emotions, cognitive flexibility (including acceptance), religion/spirituality (a framework for life meaning), social support and active coping (including exercise) (Southwick, Vythilingam, & Charney, 2005). Fostering resilience and its protective factors in individuals with diabetes is likely to improve the ability to adapt to illness stressors and result in improved QoL (Bradshaw et al., 2007).

A review of resilience training interventions for people with chronic diseases showed that there are few studies on resilience *training* with this population and that most neglected resilience protective factors (Kim, Lim, Kim & Park, 2018). We know of only two published resilience training studies for adults with diabetes. One program involved 10 x 90-minute group sessions over five weeks, with a focus on developing positive health behaviours via four components: self-efficacy, locus of control, purpose in life and social support (Bradshaw et al., 2007). The experimental group (n=37), relative to the usual care comparison group (n=30), improved in positive coping, diabetes-related stress, self-awareness, diabetes self-management, healthy eating, and physical activity at three-month follow-up (Bradshaw et al., 2007). The Diabetes Coaching Program involved 4 x 2 hour weekly class sessions focused on resilience education and diabetes self-management (predominantly diabetes-specific nutrition education) and 8 x 1.5 hour biweekly, informal, non-structured support group sessions (Steinhardt et al, 2009). Results (n=12) showed improvements from baseline to post-intervention on measures of diabetes empowerment and self-management; but not resilience, perceived stress, or coping (Steinhardt et al, 2009).

Most of the psychological interventions used with people with diabetes have been based on cognitive and behaviour therapy (CBT). Recent variants of CBT have evolved called 'third generation' CBTs. One of the most widely used and researched of this group is Acceptance and Commitment Therapy (ACT; Hayes, Strosahl & Wilson, 2011). However, few studies have applied ACT and other third generation CBTs to people with diabetes. Broadly, the goal of ACT is to increase psychological flexibility, which involves behaving consistently with one's chosen values even with unwanted intrusive internal experiences like emotional discomfort or self-critical thinking (Hayes et al., 2011). Psychological flexibility is the cornerstone of psychological health and is related to resiliency (Kashdan & Rottenberg, 2010). As such, an ACT intervention can increase resilience by improving an individual's psychological flexibility. According to the ACT framework, six core processes enhance psychological flexibility: (1) acceptance: the active awareness of internal experiences without changing their frequency or form; (2) cognitive defusion: maintaining psychological distance from mental experiences (e.g., thoughts) rather than taking them literally or suppressing them; (3) contact with the present moment: ongoing non-judgmental and responsive awareness of the present moment (cf. mindfulness); (4) self-as-context: flexible perspective-taking enabling awareness of one's own flow of experiences, without attachment to them and without them unduly influencing behaviour; (5) values: freely chosen verbally constructed and personally meaningful life directions; (6) committed action: values-guided effective action. In his review of stress management interventions for diabetes, Morris (2011) recommended ACT-based interventions as an alternative approach to CBT, noting the benefits of mindfulness, acceptance and values.

The ACT processes are likely to promote resilience through increasing values-based actions even in the presence of emotional and mental discomfort (Thompson, Arnkoff, & Glass, 2011; Hubert-Williams, Storey, & Wilson, 2015). ACT-based interventions have been associated with increases in resilience and related protective factors (e.g., Pakenham, Mawdsley, Brown, & Burton, 2018). In addition, mindfulness and acceptance, core processes in ACT have been shown to increase resilience (e.g., Thompson et al, 2011).

The research on ACT for adults with diabetes is still emergent and has not focused on resilience as a key outcome. Three randomised controlled trials of group ACT-based interventions showed that compared to control groups, the ACT participants showed greater improvements in diabetes self-management (Gregg et al., 2007; Hoseini et al., 2014; Shayegian et al., 2016), treatment adherence (Gregg et al., 2007) and effective coping strategies (Shayegian et al., 2016). In a quasi-experimental study, an ACT group-based intervention was associated with improvements in mental health for women with Type II diabetes (Kaboudi et al., 2017). Focusing on one of the core ACT processes, a systematic review of mindfulness-based interventions for diabetes showed that such interventions were effective in reducing anxiety, depression and distress, but demonstrated mixed outcomes for improving diabetes-related physiological outcomes (Noordali et al., 2017).

The intervention used in this study was the group-based REsilience for Adults everyDaY (READY) Program. READY is an ACT-informed generic resilience training program that can be tailored to specific contexts (Burton et al., 2010) and its application to people with diabetes is evaluated in the present study. Previous evaluations of READY have shown improvements in resilience and QoL, and resilience related protective factors including psychological flexibility, physical activity, mindfulness, subjective wellbeing, and health behaviours in a tertiary education worksite sample (Burton et al., 2010), colorectal cancer survivors (Hawkes et al., 2013; Hawkes et al., 2014), and people with multiple sclerosis (Pakenham et al., 2018). The READY program is described in more detail elsewhere (Burton, Pakenham, & Brown, 2009). It targets the five key resilience protective factors identified by Southwick et al's (2005) review: psychological flexibility, life meaning, physical activity, positive emotions and social connectedness.

In summary, people with diabetes are at risk for compromised QoL and elevated distress. Resilience is a process of positive adjustment to adversity and is an important predictor of QoL in people with physical disability and illness. ACT is a potentially effective intervention for promoting resilience and related protective factors (Pakenham et al, 2018). Furthermore, central to ACT are mindfulness and acceptance processes, which are related to greater resilience. In addition, ACT is based on a model of psychological flexibility; a construct which is related to resilience. There are therefore numerous potential pathways by which ACT could promote resilience and related protective factors. The resilience training program evaluated in the present study uses the six ACT processes to cultivate resilience and related protective factors.

The first aim of the present study was to explore the effectiveness of the READY Program for people with diabetes. We predicted that participants would show significant pre- to post-intervention increases in resilience and decreases in distress, which constituted the primary outcomes. We also expected increases in the resilience protective factors of psychological flexibility, mindfulness, valued living, positive affect and physical activity, which constituted the secondary outcomes. The second aim was to explore the feasibility and acceptability of the READY Program when delivered in the community to people with diabetes and investigate the suitability of a battery of measures for assessing the primary and secondary outcomes that could be included in future clinical trials of READY for diabetes.

Method

This study evaluated the READY Program (Burton et al., 2010) using a single group intervention condition design with pre- and post-intervention assessments. Data were collected via questionnaires and speedometers'. The study protocol was approved by The University of Queensland ethics committee (clearance ID: #2012000495).

Participants and Recruitment

Participants were recruited via Diabetes Australia (Queensland) e-newsletters, a university staff e-newsletter, a radio interview, and flyers distributed through General Practitioners, pharmacies, and a hospital diabetes clinic. Inclusion criteria were a self-reported diagnosis of Type I or Type II Diabetes, age greater than 18 years, fluency in English, and able to attend the weekly community-based sessions. A total of 56 people responded, all of whom were eligible and invited to participate, and of these, 28 declined participation (did not respond to further information or stated that program times, locations or dates did not suit). Of the 28 individuals offered the intervention, eight withdrew prior to commencement, and 20 participants completed the pre- and post-intervention assessments.

The mean age of participants was 54 years (*SD* = 12.78; range 24 - 74), 70.0% were female and 75% were born in Australia. Over half the participants (60.0%) had vocational qualifications (e.g., TAFE, apprenticeship), 25% had university education, and 60% were engaged in part-time or full-time paid employment. Most (75%) of participants stated that it was difficult all or most of the time to manage on their income. Most (70.0%) participants had Type II diabetes. The mean BMI (derived from self-reported height and weight) was 33.07 (*SD* = 10.21). The majority of participants self-reported their general health as 'good' (35.0%), 'fair' (25.0%), or 'poor' (35.0%), with only one participant self-rating their health as 'very good', and no participants rated their health as 'excellent'.

Intervention

Ten of the eleven standard READY program modules were used in the present study. The mid-program review was excluded because of time constraints. Participants received a workbook that includes written notes, critical reflection and structured learning activities to complete, and a CD of guided mindfulness meditations. Specific reflection and learning activities comprise the READY Personal Plan, which is a personalised resource to help participants apply the generalised information to their specific context and individual style. Details of the program content are summarised in Table 1.

Procedure

The READY Program (Burton et al., 2010) was delivered in 10 group weekly sessions to three separate groups of participants held in community locations (e.g., local library and church hall) in Brisbane, Australia. The first 8 sessions were each two hours in duration and the last two were each one hour. Measures were administered to participants by the program facilitator at the start of the first session and at the end of the last session. The group facilitator was a postgraduate clinical psychology student with formal training in ACT, who received fortnightly group peer supervision from the READY Program authors for the duration of the program delivery. Intervention fidelity, although not directly assessed, was monitored through this regular supervision and supported by the use of the READY Program Facilitators Manual.

Measures

Resilience. The 15-item Resilience Scale (Neill & Dias, 2001) assessed resilience. Items are rated on a 7-point scale (1 *disagree* to 7 *agree*), and summed; higher scores indicate higher resilience.

*Distress***.** *Diabetes-related distress* was assessed with the 20-item Problem Areas in Diabetes scale (Polonsky et al., 1994). The scale measures global emotional adjustment to diabetes (Welch et al., 1997). Items are rated on a 5-point scale (0 *not a problem* to 4 *serious problem*) where higher scores indicate greater emotional distress. *Depression, anxiety and stress* were assessed with the standardised widely used 21-item Depression Anxiety Stress Scale (Lovibond & Lovibond, 1995). Items are scored on a 4-point scale (0 *not at all* to 3 *most of the time*) and summed, where higher scores indicate greater distress (Lovibond & Lovibond, 1995).

Psychological flexibility. The Acceptance and Action Questionnaire II (Bond et al., 2011) assessed psychological flexibility. Seven items are rated on a 7-point scale (1 *never true* to 7 *always true*) and summed. Items were reverse scored so that higher scores indicate greater psychological flexibility.

Positive affect. The positive affect subscale of the Positive and Negative Affect Schedule (Watson & Clark, 1988) assessed positive emotions. Twenty items are rated on a 5 point scale (1 *very slightly or not at all* to 5 *extremely*) and summed, with higher scores indicating a greater positive affect.

Mindfulness. The Mindful Attention Awareness Scale (Brown & Ryan, 2003) measured mindfulness. Fifteen items are rated on a 6-point scale (1 *almost always* to 6 *almost never*) and responses are summed; higher scores reflect a greater mindfulness.

Values. The Valued Living Questionnaire (Wilson & Groom, 2002) was used to measure the importance of certain life domains and the consistency of living according to values in these domains. Sixteen items are rated on a 10-point scale (1 *not at all* to 10 *extremely*) where higher scores indicate greater importance and consistency. A valued living composite is calculated by multiplying the importance and consistency scores for each domain then establishing the mean of these products (Wilson et al., 2010).

Physical Activity. Items from The Active Australia Survey (Australian Institute of Health and Welfare, 2003) were used to assess the time spent in each of walking, vigorous intensity activity, and moderate intensity activity in the previous week. The total time spent in physical activity (weighted minutes/week) was derived by summing responses, with vigorous activity weighted by two to account for the higher intensity (Australian Institute of Health and Welfare, 2003). Pedometers (Yamax Digiwalker SW700, Yamax Corporation, Tokyo, Japan), were used as an objective measure. Participants were asked to wear the pedometer during all walking hours for seven consecutive days and record the number of steps taken each day, and the time the pedometer was worn each day. Valid data was defined as when the pedometer was worn more than nine hours of the day. The step counts per (valid) day were summed and then averaged across the number of days to develop a mean step count per day. The 5-item *Sitting Time Questionnaire* (Marshall et al, 2009) assessed time spent sitting (sedentary behaviour) on a usual day during the past week in each of five domains: travelling, working, watching television, using a computer, or other leisure time. Sitting time (mins/day) was derived by summing data across domains.

Program Feasibility and Acceptability. Participant attendance records were kept for each session by the facilitator, and reasons for non-attendance were recorded at subsequent sessions. The post-intervention questionnaire included items to obtain participant feedback on the program. Five items required participants to rate their level of agreement (1 *strongly disagree* to 5 *strongly agree*) with statements gauging program-related satisfaction, helpfulness and enjoyment, likelihood of recommending the program to others, and the extent to which they believed their resilience had increased. Three open-ended questions inquired about the most helpful *READY* program skills, the impact of the program on their management of diabetes, and suggested improvements to the program.

Data Analysis

The Statistical Package for the Social Sciences Version 19 (SPSS-19) was used for all analyses. Regarding examination of changes from pre- to post-intervention on the primary and secondary outcomes both parametric and non-parametric analyses were conducted due to the mix of normally and non-normally distributed data across the outcome variables. Both sets of analyses yielded an identical pattern of results. Given the similarity in results, parametric analyses are reported. Hence, results of the paired *t*-tests are reported. Although a pilot study, given the number of planned comparisons, a more stringent significance level of $p<0.01$ was applied to reduce the probability of Type II error. Cummins' (2012) recommendations were used to include and interpret effect sizes and their confidence intervals (CI), where .0 - .1 is a non-important effect size, .1 - .3 equals a small to medium effect size, .3 - .5 is a medium to large effect size, and greater than .5 equals a large effect size. Qualitative data from the open-ended questions gauging intervention feasibility and acceptability were analysed using Braun and Clarke's (2006) methodology for thematic analysis.

Results

The results of pairwise *t*-tests are summarised in Table 1, including descriptive data (means and standard deviations) and relevant statistics (t values, r^2 and confidence intervals).

Changes in Primary and Secondary Outcomes

Consistent with predictions related to the first study aim, there were significant improvements in the primary outcomes. Specifically, there were pre- to post-intervention increases in resilience, and decreases in depression and stress (p<0.01), and a trend towards improvements (decreases) in diabetes-related distress and anxiety (p<0.05). Also as expected there were significant improvements (increases) on the resilience protective factors of positive affect, psychological flexibility, valued living and pedometer assessed physical activity, and decreased self-reported sitting time/day (p<0.01). The increase in mindfulness approached significance (p<0.05). There was a non-significant positive trend in self-reported time spent in physical activity.

The improvement in resilience evidenced a medium effect size. The effect sizes of improvements for all other variables were small to medium: distress; diabetes-related distress; depression; anxiety; stress; positive affect; psychological flexibility; valued living; self-reported activity (minutes per week); step count; and self-reported sitting time.

Feasibility and Acceptability

Most participants (90.0%) attended more than half the program and over half the participants (55.0%) attended more than 80.0% of sessions. Two participants (10.0%) attended 40.0% or less of the sessions. The most common reasons given for missing sessions were time conflicts with work and family demands.

Participant feedback on the program was very positive. The mean ratings for program-related satisfaction (*M* = 4.70; *SD* = .47), helpfulness (*M* = 4.45; *SD* = .60) and enjoyment (*M* = 4.75; *SD* = .44) were all close to the highest rating of five. Participants rated very highly the extent to which the program had increased their resilience (*M* = 4.60; *SD* = .50). The majority nominated ACT skills as most helpful, in particular, defusion, mindfulness and acceptance. All participants agreed that they would recommend the program to others with diabetes. Suggested program improvements from five participants were to include more diabetes specific information (including referral options), reduce the duration of the program, and conduct the program online.

The majority of participants described positive impacts of the program in four broad areas: improved ability to manage the illness (*n* = 7; e.g., "I am more aware of bad habits and how to not do them"); increased motivation to manage diabetes effectively (*n* = 6; e.g., "increased my determination to take my health seriously"); improved ability to cope with diabetes (*n* = 3; e.g., "feeling better able to cope with the diabetes"); and increased acceptance (*n* = 3; e.g., "more accepting of limitations"). One participant was unsure whether the program had an impact on diabetes management, and another stated that the program had no such impact.

Discussion

As predicted, participants attending the READY Program showed pre- to post-intervention improvements in resilience, distress and the resilience protective factors: psychological flexibility, positive emotions, values and physical activity. Program attendance showed good intervention engagement and participant feedback evidenced high satisfaction with the Program and self-reported improvements that converged with the statistically significant intervention effects.

This study showed improvements in distress that were consistent with improvements shown in prior resilience training research with non-diabetes groups (e.g., Dusek et al., 2009;

Sood et al., 2011) including previous evaluations of the READY Program (e.g., Pakenham et al, 2018). Similarly, prior evaluations of READY with chronically ill and non-clinical samples have also shown increases in resilience (Pakenham et al, 2018), and related protective factors including psychological flexibility (Hawkes et al., 2013, Pakenham et al, 2018, Burton et al., 2010), mindfulness, valued living, physical activity and positive emotions (Burton et al, 2010). In the present study, the strongest improvement was evident for resilience with a moderate effect size, and the effect sizes for changes on the other outcomes were in the small to medium range.

Importantly, in the present study the statistically significant improvements in the primary and secondary outcomes were reflected in the participant's qualitative feedback. The majority of participants reported that the program had helped them to become more resilient and to better manage their diabetes. Program feasibility was further supported by the high intervention satisfaction ratings and attendance rates, and the fact that all participants indicated that they would recommend the READY Program to others with diabetes.

There was a significant increase in average daily step counts following the intervention (mean difference 3366 steps/day) and a significant decrease in sitting time (mean difference -137 mins/day) and a suggested positive trend in self-reported physical activity. This may indicate that, while participants did not increase time spent in moderate-vigorous exercise, they may have increased light intensity activities, such as slow walking. These results are particularly important not just for resilience and wellbeing outcomes, but because physical activity is a key aspect of diabetes management (Craig et al, 2011; Colagiuri et al, 2009) and sedentary behaviour increases the risk of cardiovascular and all-cause mortality (Dunstan et al, 2010). Bradshaw et al. (2007) also showed improvement in physical activity following diabetes resilience training that focussed on diabetes self-management. As the *READY* program included only one session on physical activity and did not focus on diabetes self-management, the physical activity improvements are promising. An earlier application of the ACT components of the READY Program with people with cancer also showed improvements in physical activity (Hawkes et al, 2013). Other research has demonstrated positive associations between mindfulness and physical activity (Roberts & Danoff, 2010; Ulmer, Stetson, & Salmon, 2010), and suggested that mindfulness may improve intrinsic motivation for (Ruffault et al, 2016), and mediate satisfaction with (Tsafou et al, 2016), physical activity.

In comparison to other published diabetes resilience training programs, the 20 hours of contact time for the READY Program was the same as that in Steinhardt et al.'s (2009) program, which demonstrated improvements on measures of diabetes empowerment and self-management, but not resilience, perceived stress or coping. The READY contact time was more than the 15 hours (over 5 weeks) in the Bradshaw et al. (2007) program, which demonstrated improvements in coping with diabetes-related stress, self-awareness, diabetes self-management, healthy eating, and physical activity at three-month follow-up. Both these programs included a focus on diabetes specific information (e.g., healthy eating, self-management), which was not part of the READY Program. Interestingly, a third or more of the READY participants described an improved ability and increased motivation to manage their diabetes effectively. There was also a marked reduction in diabetes-related distress and stress and a significant increase in physical activity, all of which contribute to better diabetes self-management.

It is important to note that the core READY Program content has not been changed in its application across a variety of chronic illnesses (e.g., cancer, diabetes, multiple sclerosis and congenital heart disease). It has been proposed that the ACT processes, along with other CBT strategies, represent generic therapeutic processes that target fundamental psychopathology processes (Hayes & Hoffman, 2017). Notably, in the present study the ACT processes were reported by most participants as particularly helpful.

Limitations of the study include the non-random sampling and an over-representation of females, which limits the generalisability of findings. As this study was a not a randomised controlled trial, we are unable to make conclusions about the efficacy of the program. In the absence of a follow-up assessment, we are unable to comment on the sustainability of these improvements. Further, there was a large number of outcome measures, which is important for the pilot examination of appropriate outcome scales to be included in future clinical trials of READY for diabetes, nevertheless this also increased the risk of Type II error. However, a more conservative significance level (p<.01) was used to protect against Type II error. Finally, it is unknown if participants had previously worn a pedometer, and if this alone may have accounted for increased steps. Given that the reactivity of pedometers appears to be transient and brief, and that the steps assessment was conducted post-intervention, it is unlikely to adequately explain the physical activity findings in the present study (Clemes & Deans, 2012).

Future research should examine the efficacy of the program in a controlled trial, the sustainability of intervention effects over the longer term, the mechanisms of change, and further refine the most appropriate outcome measures. Given participant feedback on suggested program enhancements, future applications of READY could examine the inclusion of diabetes-specific education, shorter program length, the use of online material to supplement the group intervention and delivery of the entire program online.

Findings suggest that it is feasible to implement READY as a group training program in community settings to promote resilience, emotional wellbeing and resilience protective factors in people with diabetes. Data supported the feasibility and acceptability of the READY Program for people with diabetes. Enhancing mental health and decreasing distress is especially important for this population, given the role that psychosocial variables have in shaping medical outcomes. Fostering resilience, psychological flexibility, positive affect, valued living, mindfulness and physical activity in people with diabetes is likely to enhance their coping with diabetes-related stress which, in turn, is likely to improve their lived experience of this chronic condition and reduce treatment burden and the use of medical services. Resilience training interventions, particularly those that include the core ACT processes, would be useful adjuncts to standard diabetes medical care and self-management programs.

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Table 1

Summary of READY Program Content

Content	Time allocated (mins)
Session 1 Introduction to READY	
• Orientation to program (including ground rules and rapport building)	25
• Outline of the *READY* Program and the *READY* Personal Plan	25
• Introduction to *READY* resources	
• Psycho-education on resilience and related protective factors	25
• Discussion and exercises to identify early warning signs of low resilience	25
• Review of key learnings	10
• Between session *READY* Personal Plan tasks presented	10
Session 2 Mindfulness	
• Review of previous session and *READY* Personal Plan activities	10
• Review of the *READY* resilience model	10
• Introduction to mindfulness	10
• Psycho-education on mindfulness	15

Content	Time allocated (mins)
• Practice of mindfulness exercises	45
• Individual reflection	15
• Review of key learnings	10
• Between session *READY* Personal Plan tasks presented	5
Session 3 Acceptance	
• Review of previous session and *READY* Personal Plan activities	10
• Mindfulness exercise	5
• Review of the *READY* resilience model	10
• Psycho-education on emotions and experiential avoidance	30
• Psycho-education on acceptance	10
• Acceptance experiential exercises	40
• Review of key learnings	10
• Between session *READY* Personal Plan tasks presented	5
Session 4 Defusion	
• Review of previous session and *READY* Personal Plan activities	10

Content	Time allocated (mins)
• Mindfulness exercise	5
• Review of the *READY* resilience model	5
• Psycho-education on thoughts and thought fusion	20
• Practise in identifying unhelpful thoughts	20
• Psycho-education on defusion	10
• Practise of defusion strategies	40
• Review of key learning	5
• Between session *READY* Personal Plan tasks presented	5
Session 5 Defusion and Observer Self	
• Review of previous session and *READY* Personal Plan activities	10
• Review of the *READY* resilience model	5
• Mindfulness exercise	5
• Trouble shooting defusion strategies	20
• Practise of additional defusion techniques	35
• Observer-self metaphors and experiential exercises	30

Content	Time allocated (mins)
• Review of key learnings	10
• Between session *READY* Personal Plan tasks presented	5
Session 6 Physical Activity	
• Review of previous session and *READY* Personal Plan activities	10
• Brief mid-program review	15
• Psycho-education on the benefits of physical activity for resilience	10
• Psycho-education on physical activity	15
• Psycho-education on daily step counts, pedometer use, and ways to increase step counts	10
• Physical activity planning	30
• Physical activity problem solving	20
• Review of key learnings	5
• Between session *READY* Personal Plan tasks presented	5
Session 7 Values and Meaningful Action	
• Review of previous session and *READY* Personal Plan activities	10
• Review of the *READY* resilience model	10

Content	Time allocated (mins)
• Psycho-education on values	30
• Values identification and connection	25
• Development of a values statement and related goals	25
• Review of key learnings	10
• Between session *READY* Personal Plan tasks presented	10
Session 8 Pleasurable Activities	
• Review of previous session and *READY* Personal Plan activities	10
• Review of the *READY* resilience model	10
• Psycho-education on relaxation and resilience	10
• Practise of relaxation exercises	45
• Psycho-education on pleasurable activities	15
• Review of key learnings	10
• Between session *READY* Personal Plan tasks presented	10
Session 9 Review and Future Planning*	
• Review of previous session and *READY* Personal Plan activities	10

Content	Time allocated (mins)
• Mindfulness exercise	5
• Review *READY* resilience model	20
• Review resilience building strategies	25
Session 10 Review*	
• Review of key learnings	10
• Review *READY* Personal Plan	40
• Complete post-assessment	10
• End	

* = sessions were 60 minutes

Table 2.

Pre- to Post-intervention Changes in Resilience, Distress and Resilience Protective Factors (N = 20)

			t-test			*95% CI*	
	M(SD) Pre-intervention	M(SD) Post-intervention	t [a]	r	r^2	Lower Bound	Upper Bound
Resilience	67.65 (14.70)	75.90 (15.52)	3.00**	.67	.45	-14.00	-2.50
Distress:							
Diabetes-related distress	38.88 (23.20)	28.75 (19.80)	-0.57*	-.38	.14	.65	19.60
Depression	17.00 (12.32)	9.70 (10.57)	-3.57**	.36	.13	3.02	11.57
Anxiety	9.40 (10.74)	6.20 (8.41)	-2.19*	.36	.13	.14	6.36
Stress	19.20 (11.51)	11.80 (9.86)	-3.26**	.39	.15	2.65	12.15
Resilience Protective Factors:							
Positive affect	26.75 (9.30)	32.45 (9.77)	.57**	-.39	.15	-9.84	-1.55
Mindfulness	52.55 (11.82)	58.85 (12.18)	0.51*	-.37	.14	-11.89	-.71

Psychological flexibility	41.55 (8.88)	47.90 (8.75)	.65**	-.49	.24	-9.81	-2.89
Valued Living	234.78 (96.31)	285.28 (79.68)	.56**	-.39	.15	-89.86	-11.14
Physical Activity:							
Self-reported time (weighted mins/week)	136.45 (114.03)	155.00 (112.62)	.36	.17	.03	-78.59	55.59
Step Count (mean steps/day)	4,732.18 (2339.39)	8,098.24 (3,453.64)	6.44**	.51	.26	-4474.77	-2257.35
Self-reported sitting Time (mins/day)	607.25 (245.39)	470.25 (159.76)	-.68**	-.52	.27	-52.40	-221.40

[a] *df* = 19. * *p* <.05. ** *p* <.01.