Title: *Multiple components of fitness improved among overweight and obese adolescents following a community-based, lifestyle intervention*

Running Head: Fitness changes obese adolescents

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Abstract

Fitness is an important component of health and obese adolescents regularly have poor fitness. Unfortunately, few have assessed the impact community-based lifestyle interventions on multiple components of fitness. The purpose of this study was to assess the impact of participation in a community-based intervention involving adolescents and parents on multiple components of fitness of obese adolescents. In a within-subject, waitlist controlled clinical trial with 12 month follow-up in Western Australia, participants (n=56) completed multiple fitness measures at baseline, immediately prior to beginning an 8-week intervention, and at 3-, 6-and 12 months during a maintenance period. Performance on the shuttle walk was improved immediately post-intervention (increase of 42.8 m, 95% CI: 7.5, 78.2) and at 12-months post-intervention (increase of 44.6 m, 95% CI: 1.3, 87.8) compared to pre-intervention. Muscle performance of quadriceps, and deltoids were improved post-intervention (increase of 1.1 (95% CI: 0.1, 2.1) kgF and 1.0 (0.02, 2.1) kgF respectively and all muscle performance measures were improved at 12 months following the intervention. There were no changes in waist circumference. A community-based, lifestyle program such as CAFAP may be a viable strategy for improving fitness in overweight adolescents.

Keywords: *behaviour, self-detrmination theory, exercise, body composition, humans*

Introduction

Fitness, particularly cardiorespiratory fitness, is an important component of health. Higher levels of fitness are related to many positive health outcomes in adults, and have a strong negative association with cardiometabolic risk in children (Rizzo, Ruiz, Hurtig-Wennlof, Ortega, & Sjostrom, 2007). Unfortunately, many overweight and obese adolescents have low levels of fitness and these low levels of fitness likely track into adulthood (Alberga, Sigal, Goldfield, Prud'homme, & Kenny, 2012). Adolescence may be a critical time to intervene to improve fitness, as adolescents are becoming independent and forming habits they will carry into adulthood (Alberga et al., 2012). Fortunately fitness can be improved by increasing physical activity to a sufficient dose and maintaining for a sufficient period (Church, 2009).

Of the interventions aiming to improve the fitness of obese adolescents, several have been intensive, supervised, structured exercise or inpatient programs that are effective in the short term (Karner-Rezek et al., 2013) but cannot be easily sustained or disseminated to a wider population. Therefore community-based interventions have been recommended (Hoelscher, Kirk, Ritchie, Cunningham-Sabo, & Acad Positions, 2013).

The majority of community interventions attempting to improve fitness in adolescents have been conducted in schools and many have included all adolescents without specifically targeting overweight and obese adolescents who may benefit the most from intervention (Dobbins, Husson, DeCorby, & LaRocca, 2013). There have been several non-school-based community interventions with adolescents but they have had limited success at improving the fitness of overweight adolescents (Davis et al., 2012; Resnicow, Taylor, Baskin, & McCarty, 2005). Their limited success may be due to little family involvement (Davis et al., 2011; Davis et al., 2009; Resnicow et al., 2005), no long term follow-up (Evans et al., 2009; Shaibi et al., 2012), and only assessing single components of fitness (Davis et al., 2009; Davis et al., 2012; Eliakim et al., 2002; Evans et al., 2009; Resnicow et al., 2005; Shaibi et al., 2012). Only two studies have involved parents (Eliakim et al., 2002; Shaibi et al., 2012), yet interventions in community settings that include families may present the best opportunity for sustainable behaviour changes. Long term changes are needed for interventions to be effective, yet only three studies have examined fitness outcomes at least 6 months post-intervention (Davis et al., 2012; Eliakim et al., 2002; Resnicow et al., 2005). Whilst there are multiple components to health-related fitness including cardiorespiratory endurance, muscular performance, and body composition (Ganley et al., 2011), and each component has important and potentially independent health effects (Ganley et al., 2011), only Davis et al. (Davis et al., 2011) has examined both cardiorespiratory and muscular fitness and this study had no long term follow-up or family involvement.

Curtin University's Activity, Food and Attitudes Program (CAFAP) was an 8 week community-based, family-centred lifestyle program for overweight adolescents targeting physical activity, sedentary and nutrition behaviours (Straker et al., 2014; Straker et al., 2012). The physical activity outcomes have been published in detail (Howie, Olds, McVeigh, Abbott, & Straker, 2015; Straker et al., 2014), with few positive changes in physical activity and Body Mass Index (BMI). Fitness, a set of attributes including cardiorespiratory endurance, muscular strength and endurance, body composition and flexibility, is a separate construct from physical activity behaviour with important, independent health implications (Caspersen, Powell, & Christenson, 1985; Myers et al., 2004). There is little information on changes in fitness beyond the short-term in overweight and obese adolescents participating in a community, lifestyle intervention (Alberga, Frappier, Sigal, Prud'homme, & Kenny, 2013) despite the need for such interventions. Thus an examination of the fitness changes in adolescents participating in CAFAP is warranted. The purpose of this paper is to report the effects of the 8 week face-to-face intervention on indicators of cardiovascular and muscular fitness immediately post-intervention and at 3-, 6-, and 12-month intervals after the culmination of the intensive intervention period.

Methods

Study design

The detailed protocol for this study has been previously published (Straker et al., 2012). Briefly, the study used a staggered entry, waitlist control design as shown within Figure 1. In this within-subject design which reduces error variances, changes during the three-month waitlist period were used as the control comparison representing individual trajectories. The decision not to include a separate control group was taken because it was considered unethical to withhold an intervention with a strong evidence base from an at-risk group, however, staggered entry increased external validity, and the within subject control period aided internal validity. Measurements were taken at baseline, at pre-intervention which was 3 months following baseline but prior to beginning the intervention, immediately following the 8-week intervention, and at 3-, 6-, and 12-months maintenance following the intervention. The trial was registered with the Australia and New Zealand Clinical Trials Registry (# ACTRN12611001187932), received ethical approval from the Curtin University Human Research Ethics Committee (HR105/2011), and complied with Transparent Reporting of Evaluations with Nonrandomized Designs (TREND)requirements for non-randomized clinical trials (Straker et al., 2014).

Participants

Participants were recruited from three areas (2 urban, 1 rural) in Western Australia with high proportions of low socio-economic residents through medical referrals, radio and newspaper advertisements, and flyers across three waves to balance seasonal effects. Cohorts ranged from 6 to 8 adolescents. To be eligible, adolescents needed to be between the ages of 11 and 16 and have a BMI greater than the 85^{th} percentile for age and sex.(USDA/ARS Children's Nutrition Center, 2003) Adolescents were ineligible if they were unable to attend sessions twice per week or did not pass a medical screening prior to participation. They were required to submit a letter from their GP with approval to participate with participants excluded from the study if obesity was related to a diagnosed genetic or endocrine disorder, were currently receiving treatment for a psychiatric disorder, or if the doctor considered participation unsafe for any other reason. A total of 69 participants entered the study with 44 completing the intervention and 34 remaining at 12-months follow-up. A detailed description of attrition is published elsewhere (Straker et al., 2014).

Intervention

The intervention was based on self-determination and goal setting theories (Fenner, Straker, Davis, & Hagger, 2013). Adolescents and parents participated in two-hour sessions at a community site, twice per week for eight weeks. Each session included both 45-minutes of group exercise for the adolescent including games and activities that targeted both cardiorespiratory and strength exercises, and an educational session together with parents and details, as described elsewhere (Straker et al., 2014). Facilitators were a multidisciplinary team including a physiotherapist, dietician and psychologist. During the 12 month maintenance phase, adolescents received theory-supported SMS messages (which are described in detail elsewhere (Smith, Kerr, Fenner, & Straker, 2014)) and telephone calls from facilitators at a decreasing frequency from once per fortnight (two weeks), to once per month, and finally once per school term.

Outcome Measures

Cardiorespiratory Fitness. All fitness tests were administered by research staff at a community location. A modified shuttle walk test was used to assess cardiorespiratory fitness. The modified test used a 10 meter rather than 20 meter distance and was developed for populations with low levels of fitness (Klijn & van der Baan-Slootweg, 2007) as it includes more lower performance levels to reduce the risk of a floor effect in assessing obese adolescents. The shuttle test has a high reliability (ICC=0.92) in obese adolescents and is highly correlated with maximal oxygen uptake tests (r=0.79) (Klijn & van der Baan-Slootweg, 2007).

Muscular performance. Muscular performance was assessed using multiple measures. The strength of the biceps, quadriceps and deltoids was measured using a standard ‘break’ manual muscle testing protocol of isometric contractions (Sloan, 2002). Manual muscle testing has shown to have a test-retest reliability of 0.72 to 0.90 in 8 to 10 year-old children (Dawson, Quinn, & Vroman, 1992) and a similar manual muscle testing protocol has shown to be valid compared to Cybex dynamometry in adolescents aged 3 to 18 (Hébert et al., 2011). Peak force in kilogram-force was measured using a force transducer manual muscle tester (Lafayette Instruments, Lafayette, IN, USA). Testing was performed on the non-dominant limb three times and an average of the three trials was calculated.

The Sargent's vertical jump test was used to assess lower limb muscle power. The test has a high reliability (ICC=0.96) and is valid compared to other vertical jump tests (Markovic, Dizdar, Jukic, & Cardinale, 2004). The vertical jump test is widely used to assess power outputs of lower limbs in school aged children and adolescents as it relates to their ability to participate in many daily activities for young people such as running, cycling and climbing stairs. It provided an alternative and complimentary fitness measure to quadriceps isometric strength. Three jumps were performed, and the greatest vertical distance to the nearest 0.1 cm was used.

The curl-up test from the Canadian Standardised Test of Fitness was used to assess abdominal muscular endurance (Faulkner, Sprigings, McQuarrie, & Bell, 1989). This dynamic test of abdominal endurance has been shown to be reliable across raters and days (ICC=0.89) (Moreland, Finch, Stratford, Balsor, & Gill, 1997). Participants completed as many partial curl-ups as possible within one minute.

Body composition. Waist circumference was measured horizontal at the umbilicus following normal expiration to the nearest 0.1 cm using an inelastic tape measure. To provide a more comprehensive representation of body composition, the previously published BMI results are presented. Height was measured by research staff to the nearest 0.1 cm and weight was measured using a calibrated scale to the nearest 0.1 kg. BMI and age and sex standardized BMI z-scores were calculated (USDA/ARS Children's Nutrition Center, 2003).

Analysis

All analyses were conducted using Stata 13/IC 13.0 for Windows (StataCorp LP, College Station TX, USA). Data were screened for normality using histograms and multiple measures of location. Due to slight departures from a normal distribution, standard errors for estimates and statistical tests were bootstrapped using 1000 replications.

Descriptive statistics were calculated and baseline variables of completers were compared to drop-outs using t-tests and X^2 tests. There were no significant differences between groups in baseline fitness variables. Only participants who attended at least two measurement occasions were included in the models (n=56). To assess the effect of the intervention on fitness outcomes, individual linear mixed models were used for each dependent variable. Random intercepts were used to account for within-person correlation of repeated measures and maximum likelihood estimation used all available data. To test a priori hypothesis, the estimated mean scores at each time point (baseline, post-intervention, 3-months, 6-months, 12-months) were contrasted with pre-intervention values. Additionally, the rate of change in dependent variables across each period (intervention period and maintenance periods) were compared to the rate of change during the waitlist period. Monthly rates are presented to account for the different period durations. Model fit was assessed using residual plots and diagnostics. While no explicit adjustments for multiple comparisons were made, results are displayed as 95% confidence intervals with *P* values to 3 decimals.

Results

Baseline characteristics can be seen in Table 1 with the intervention results summarized in Table 2 and Figure 2.

Cardiorespiratory fitness

Performance on the shuttle walk was improved immediately post-intervention (increase of 42.8 meters, 95% CI: 7.5, 78.2, *P* =.018) and at 12-months post intervention (increase of 81.3 meters, 95% CI: 39.8, 122.8, *P* =< .001) compared to pre-intervention as seen in Table II. The rate of change was significantly greater (*P* =.047) during the intervention period (21.4 meters per month, 95% CI: 3.7, 39.1) compared to the waitlist period (-4.9 meters per month, 95% CI: -17.1, 7.3) as shown in Figure 2.

Muscular Performance

Quadriceps (increase of 1.1 kgF, 95%CI: 0.1, 2.1, *P* =.030) and deltoids (increase of 1.0 kgF, 95%CI: 0.02, 2.1, *P* =.044) improved post-intervention and quadriceps, biceps and deltoids were improved at 12-months after the intervention. Compared to vertical jump height at pre-intervention, height at 3-months (increase of 1.7 cm, 95%Ci: 0.2, 3.2, *P* =.029), 6-months (increase of 1.7 cm, 95%CI: 0.001, 3.7, *P* =.050), and 12-months (increase of 2.6 cm, 95%CI: 0.9, 4.3, *P* <.01) following the intervention was significantly greater, although it was also improved from baseline to pre-intervention (2.9 cm, 95%CI: 1.5, 3.4, *P* <.01). Curl-up performance was improved at 12-months following the intervention compared to pre-intervention (increase of 11.6 curl-ups per minute, 95%CI: 3.4, 19.8, *P* =.006). Rates of change were not significantly different for all muscle measures.

Body Composition

There were no significant differences in waist circumference at each time point, although the rate of change during the maintenance period (0.2 cm per month, 95%CI: -0.02, 0.3) was significantly greater (*P* =.033) than the rate of change during the waitlist period (-0.5 cm per month, 95%CI: -1.1, 0.1). As previously reported, BMI z-scores were significantly lower at 6- and 12-months post intervention compared to pre-intervention (Straker et al., 2014). However, there were no significant differences in the rate of change between waitlist, intervention and maintenance periods.

Discussion

Adolescents who participated in CAFAP improved cardiorespiratory fitness and muscle performance with minimal changes in body composition. After the 8-week intervention 3 out of 9 outcomes showed improvements compared to pre-intervention cardio respiratory fitness and quadriceps and deltoids strength), and 7 out of 9 outcomes (all except BMI and waist circumference) were improved at 12 months. Furthermore, many benefits obtained did not decline for up to one year after the end of the intervention.

Overall, the participants in the current study had low levels of cardiorespiratory fitness at baseline as estimated from the shuttle walk. The mean distance in the modified shuttle test completed by participants in the current study at baseline was similar to that of another sample of obese adolescents (Klijn & van der Baan-Slootweg, 2007) and a sample of children with cystic fibrosis at hospital admission (Cox, Follett, & McKay, 2006). Therefore, the cardiorespiratory fitness level of the participants in this study approximated that of a population with serious lung disease, highlighting the urgent need to improve fitness in this population.

Fortunately, with participation in a community and family intervention that focused on healthy lifestyle behaviours, the participants were able to improve upon their performance on the shuttle walk by 6 percent immediately after the intervention. There are few studies of similar interventions in this population to compare the magnitude of these improvements. Davis et al. reported significantly increased cardiorespiratory fitness by 15 percent in their exercise groups compared with controls (Davis et al., 2011). Using a 20-meter shuttle run test to assess cardiorespiratory fitness Resnicow et al. found no change following six months of a church-based intervention.(Resnicow et al., 2005) It is unknown what a clinically meaningful increase in cardiorespiratory fitness is in this population, but as with adults, it is expected that there is a dose-response relationship between fitness and health outcomes and even small improvements in cardiorespiratory fitness may have important health implications, especially for an unfit population (Church, 2009).

Muscular performance was also poor among study participants. The mean vertical jump height at baseline was lower than a normative sample of 14 year-old adolescents (Taylor, Cohen, Voss, & Sandercock, 2010). Although, the baseline values of muscular performance obtained by the participants in our study were poor, they sustained improvement over the study period, independent of small changes in body weight. The participants in the current study were able to increase their muscle performance following the 8-week CAFAP intervention, similar to a 16-week nutrition and strength training intervention that improved bench press performance

(Davis et al., 2009). However, the previous study was specifically a strength training intervention, whereas CAFAP targeted general physical activity behaviour and was only 8-weeks of supervised intervention.

Despite improvements in cardiorespiratory fitness and muscle performance, there were minimal changes in body composition following the 8-week intervention. There was only a slight reduction in BMI z-scores at 6 and 12-months, despite improvements in cardiorespiratory fitness and muscle performance. The current study found no improvements in waist circumference, compared to Davis et al. who noted a decreased waist circumference in the exercise group (−3% vs +3%; $P < 0.001$). Body composition measures may have had limited changes as body composition is also dependent on energy intake and there were no overall changes in energy intake.(unpublished data)

Cardiorespiratory fitness and fatness have separate and joint health implications. Improving fitness through physical activity can improve markers of cardiometabolic health including inflammation and insulin sensitivity independent of changes in fatness (Gutin & Owens, 2011). Additionally, cardiorespiratory fitness may be more important than fatness for long-term outcomes including all-cause mortality (Church, 2009). Interventions with overweight and obese adolescents should stress these benefits of healthy lifestyle changes regardless of weight loss to prevent participants from becoming frustrated with minimal to no changes in weight. Additionally, because of the added difficulty of weight-bearing during aerobic activities for obese adolescents, it may be easier for previously inactive overweight and obese adolescents to start a strength program and obtain improvements in muscle performance (Alberga, Sigal, & Kenny, 2011).

This is the first study to the authors' knowledge to show additional improvements in fitness up to 12 months post-intervention. Few other studies have followed participants after an intervention, and of the two that have, Davis et al found decreases in strength after an 8 month maintenance intervention (Davis et al., 2012) and Resnicow et al found no differences in shuttle run performance after one year following intervention (Resnicow et al., 2005). The 12-month maintenance of fitness outcomes from CAFAP may be a result of the focus on changing behaviour and the involvement of the family to provide a need-supportive environment.

Because of high attrition contributing to a low number of participants completing the full study, it was not possible to test if the changes in fitness were mediated by any changes in physical activity behaviour (Straker et al., 2014). However, the levels of attrition seen in the current study are consistent with those typical in this population (Evans et al., 2009). Future research is needed to see if this program can be effective in diverse populations.

Due to ethical concerns with a no treatment control, rather, this study used a double pre-test waitlist period to provide a within subject comparison period. One limitation of the lack of a concurrent control group is the inability to delineate any age-related changes in fitness. It is possible the changes seen, particularly in the maintenance period were due to developmental changes. Cardiorespiratory fitness has been shown to increase in Australian boys, but not girls, until the age of 17 (Catley & Tomkinson, 2013). However, the age-related changes for overweight and obese adolescents specifically are unknown. Two similar interventions using control groups in overweight and obese adolescents found small decreases to no change in cardiorespiratory fitness in the control groups after 4 to 8 months (Davis et al., 2011; Resnicow et al., 2005). And in an 8 month maintenance intervention, Davis et al found decreases in both groups in bench and leg press (Davis et al., 2012). Additionally, when body weight was added to the current models to account for potential age-related changes in body mass, the improvements in fitness remained. Thus, it is plausible that the improvements in fitness seen during the intervention and likely the maintenance period of the current study may be beyond improvements that would occur with typical age-related development. While it is acknowledged that physical activity and cardiorespiratory fitness are often correlated, they are independent (Myers et al., 2004). In the current study, the correlation between distance on the shuttle test and moderate-to-vigorous activity was 0.28 across all time points. It is interesting to note that there were improvements in multiple components of fitness despite only small positive changes in objectively measured physical activity (Howie et al., 2015; Straker et al., 2014). However, physical activity was measured by accelerometers which are less likely to detect resistance exercises that would lead to many of the improvements seen in muscular strength. Future research is needed to explore the health implications of improved physical activity compared to improved fitness in overweight and obese adolescents and what individual, environmental and behavioural factors may be contributing to changes in fitness. For example, interventions or individuals who improved physical activity levels may receive different health benefits than those who solely improve multiple or single components of fitness. These differential findings may lead to targeted intervention messages to increase physical activity or fitness and aid in the selection of outcomes for intervention trials.

Conclusion

Overweight and obese adolescents who participated in CAFAP were able to improve cardiorespiratory fitness and muscle performance for up to 12 months following an 8-week intervention with minimal SMS and telephone maintenance contact. Our results suggest that a program such as CAFAP could be successfully disseminated into community settings as a viable strategy for improving fitness in overweight adolescents. The improvements noted in our study support a focus on behaviour change rather than weight loss.

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Table 1: Baseline characteristics of participants

	Total	Analysis Sample	*P* Value
n	69	56	
Sex (% female)	71	70	.202
Age (years)	14.1 (1.6)	13.9 (1.5)	.046
Height (cm)	162.9 (8.6)	162.8 (8.8)	.880
Weight (kg)	87.8 (20.4)	87.3 (18.8)	.707
BMI (kg/m2)	32.8 (6.3)	32.7 (5.9)	.826
BMI-z score	2.1 (0.4)	2.1 (0.3)	.339
Waist Circumference	103.2 (13.8)	102.5 (12.0)	.375
Shuttle Test (m)	754.0 (200.4)	779.3 (202.2)	.031
Quadriceps (kgF)	7.6 (2.8)	6.8 (3.0)	.085
Biceps (kgF)	14.0 (5.1)	13.3 (5.6)	.168
Deltoids (kgF)	8.6 (3.2)	7.7 (3.9)	.124
Curl-Ups (#/min)	30.6 (10.4)	31.7 (9.9)	.054
Vertical Jump (cm)	21.6 (6.9)	21.1 (7.2)	.215

Table 2: Estimated mean (± standard error) change in fitness components (results from linear mixed models)

		Baseline	Pre	Post	3-months	6 months	12-months
Cardiorespiratory Fitness	***Shuttle Walk Distance*** *(meters)*	770.9 (13.5)	756.2 (11.2)	799.0 (12.8)*	789.6 (17.4)	792.9 (15.0)	837.5 (17.9)*
Muscle Performance	***Quadriceps*** *(kgF)*	6.8 (0.3)	6.7 (0.3)	7.8 (0.4)*	7.5 (0.4)	9.0 (0.6)*	10.4 (0.7)*
	Biceps *(kgF)*	13.4 (0.4)	12.7 (0.4)	12.5 (0.4)	13.4 (0.4)	14.4 (0.7)*	15.4 (0.9)*
	Deltoids *(kgF)*	7.8 (0.3)	7.6 (0.4)	8.7 (0.3)*	8.8 (0.3)*	10.2 (0.7)*	10.4 (0.7)*
	Abdominal Curl-Ups *(# per min)*	31.9 (0.9)	33.5 (0.9)	35.6 (1.1)	34.8 (1.2)	35.3 (1.4)	45.0 (4.1)*
	Vertical Jump *(cm)*	21.3 (0.5)*	24.2 (0.5)	24.7 (0.5)	25.9 (0.5)*	26.0 (0.7)*	26.8 (0.6)*
Body Composition	***BMI*** *(kg/m^2)*	32.8 (0.2)	33.0 (0.1)	33.2 (0.2)	33.0 (0.2)	33.3 (0.2)	33.6 (0.3)
	BMI z-score	2.14 (.01)	2.12 (.01)	2.11 (.01)	2.09 (.02)	2.07 (.02)*	2.04 (.04)*
	WC *(cm)*	102.7 (0.7)	101.1 (0.6)	100.6 (0.6)	101.2 (0.7)	99.8 (1.7)	102.5 (1.0)

* significant difference from pre-intervention at $P<.05$

Shaded column is reference time-point

Figure Legend

Figure 1: Study design of Curtin University Activity, Food and Attitudes Program with assessment occasions

Figure 2: Changes in components of fitness among overweight and obese adolescents (n=56) across intervention and maintenance periods

Figure 1: Study design of Curtin University Activity, Food and Attitudes Program with assessment occasions

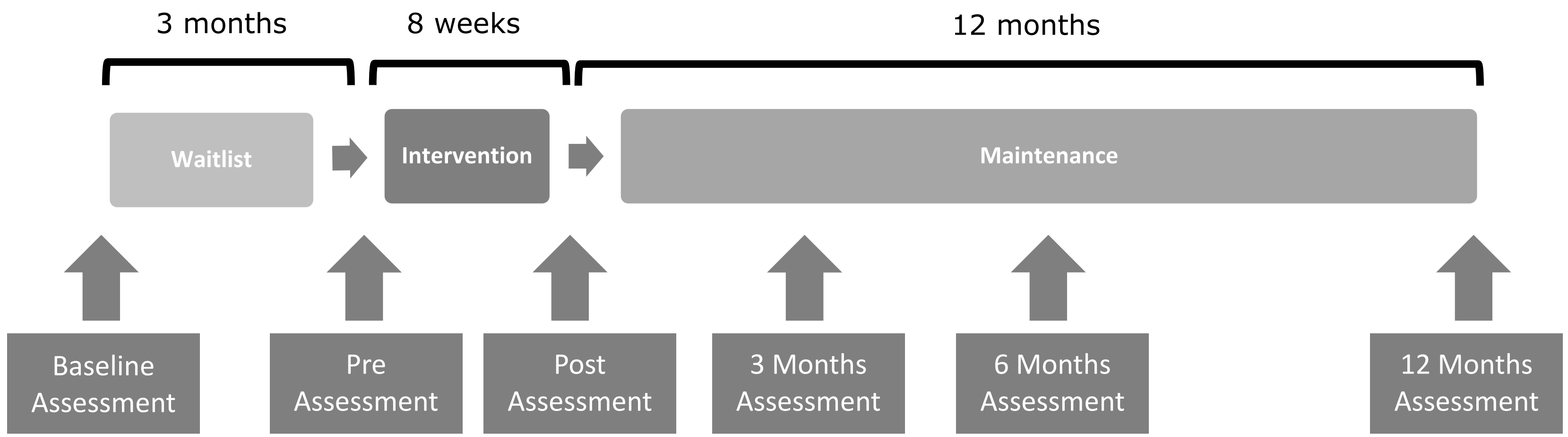

Figure 2: Changes in fitness across intervention and maintenance periods