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Finding the Optimal volume and intensity of Resistance Training Exercise for Type 2 Diabetes: The FORTE Study, a Randomized Trial

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ABSTRACT

Aim: To compare different volumes and intensities of resistance training (RT) combined with aerobic training (AT) for improvements in glycemic control and cardiovascular health for persons with type 2 diabetes (T2DM).

Methods: Participants with T2DM were stratified by HbA1c and randomized: "usual care" (RT1), which consisted of moderate intensity (50% 1-repetition maximum [1-RM]), low volume RT (initiated half-way through program); higher intensity (75% 1-RM) and higher volume (initiated at program onset) RT (RT2); or moderate intensity but higher volume RT (RT3). RT sets and repetitions were adjusted to maintain similar work and volume between RT2 and RT3. Walking or cycling (60–80% aerobic capacity) was prescribed 5 times/week, and RT was prescribed 2 times/week. An ANCOVA, adjusted for baseline and gender, assessed changes post-6 months in glycemic control (HbA1c- primary outcome), aerobic capacity and anthropometrics.

Results: Sixty-two participants (52.3 ± 1.2 years, 48% female) were randomized (RT1, $n = 20$; RT2, $n = 20$; RT3, $n = 22$). Only post-training fasting glucose, without significant HbA1c change, was different between groups (RT1–RT3 = −1.7 mmol/L, $p = 0.046$). Pre-post differences were found in pooled HbA1c (7.4 ± 0.2% [57 ± 2.2 mmol/mol] vs. 6.7 ± 0.2% [50 ± 2.2 mmol/mol], $p < 0.001$), aerobic capacity (21.5 ± 0.8 vs. 25.2 ± 0.8 ml/kg/min, $p < 0.001$), body mass (84.0 ± 2.7 vs. 83.0 ± 2.7 kg, $p = 0.022$ [DXA]), body mass index (30.8 ± 0.9 vs. 30.3 ± 0.8 kg/m^2, $p = 0.02$) and body fat (32.3 ± 1.1 vs. 31.3 ± 1.2%, $p < 0.001$). The trial was discontinued early; no HbA1c advantage was found with either RT2 or RT3 over RT1.

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Conclusions: Combined AT + RT exercise improved glycemic control, cardiovascular risk factors and body composition after 6 months for participants with T2DM, but differential effects between the prescribed intensities and volumes of RT were not found to effect HbA1c.

1. Introduction

Regular physical activity as a part of the diabetes management regime can effectively improve metabolic profiles, reduce hypertension, and decrease mortality due to vascular complications [1]. Aerobic training (AT) is traditionally prescribed, with increases in volume of exercise associated with decreases in morbidity [2]. Meta-analysis for dose response of aerobic training for glycemic improvements revealed that training at 60–80% of aerobic capacity (VO_{2peak}), at least 3 times per week for 30 min, results in a mean decrease in HbA1c of 0.7% [3]. Resistance training (RT) for T2DM management has been adopted based on positive results from randomized-controlled RT trials and combined AT and RT studies [3–5]. These studies suggest an increased benefit of combined AT + RT above either modality alone, although the difference between AT and AT + RT on HbA1c outcomes may be marginal [3]. RT is particularly important in T2DM because it improves muscle strength and endurance, influences muscle quality (decreasing intramuscular adiposity), and enhances insulin sensitivity [6,7], while combating age-related functional decline.

The "dose" of RT needed to improve glucose regulation and other risk factors in T2DM remains uncertain, particularly when RT is combined with AT. Clinical studies have compared AT + RT to AT alone [8–18], suggesting that AT + RT improved glucose control and HbA1c measures; however, variations in volume and intensity have made it difficult to ascertain the effect of RT on glucose regulation. RT trials have varied in their goals of hypertrophy (high intensity > 75% 1-repetition maximum [1-RM], low repetitions < 10) and endurance (low intensity, high repetitions), have employed different numbers of resistance exercises (3–10) targeting varying muscle groups, and differed in numbers of repetitions of each exercise (8–20), sets of exercises (2–6), frequencies per week (2–5) and intensities (40–80% of 1-RM). Some studies showing significant decreases in HbA1c include those with greater number of sets [19], as well as higher intensities [20–24] in their RT protocols. Others have shown greater benefit related to increased RT total volume [25] rather than intensity [26] [27]. Importantly, previous trials did not control for total volume of exercise or work, contributing to the difficulty in ascertaining the optimal RT protocol within the current literature [19].

The present study aimed to determine a resistance training protocol (i.e. sets of exercises, repetitions, and intensity of weight) that optimally improves glycemic control (primary objective), as well as cardiovascular risk factors and anthropometrics in T2DM (secondary objectives) while controlling for total exercise volume. The study compared training volumes and intensities from previously successful protocols in an attempt to better define optimal RT parameters. It was hypothesized that high intensity (hypertrophic) RT, aimed at increasing muscle mass and decreasing adiposity, would provide a superior training stimulus to improve glycemic control and cardiovascular risk factors than a lower volume and lower intensity (endurance) RT protocol, when the total amount of work performed is kept constant.

2. Subjects, Materials and Methods

This study randomized participants with T2DM to one of three groups; usual care (RT1), high intensity RT (RT2) or endurance RT (RT3), with the same volume of work in RT2 and RT3. The analysis was based on an intention-to-treat principle, with all participants invited for post-training assessments.

2.1. *Participants*

Participants with T2DM (fasting plasma glucose $\geq$ 7.0 mmol/L or use of insulin or oral hypoglycemic agents) were recruited at entry into the Toronto Rehabilitation Institute (TRI) *Diabetes, Exercise and Healthy Lifestyle Program* (Toronto, ON, Canada) [28] and randomized into this 6-month trial (ISRCTN97865321). The *Diabetes, Exercise and Healthy Lifestyle Program* accepts referrals from physicians, dieticians, endocrinologists and other allied health professionals. Participants were not participating in other exercise training at the time of recruitment. Individuals with previously diagnosed cardiovascular disease or complications, nephropathy, retinopathy, unrepaired hernia, or any functional impairment that would be contraindicated for participation in a high intensity (7-repetition maximum) resistance training program with concomitant aerobic training were excluded. REB approval was obtained from local Ethics Review Boards and written informed consent was given prior to participation in the study by each participant.

2.2. *Pre-randomization and testing measures*

Pre-randomization visits included a cardiopulmonary assessment; two 12-h fasting blood draws within ten days of each other for serum markers of glycemic control and cardiovascular risk and a Dual X-ray Absorptiometry (DXA) scan. The cardiopulmonary assessment was a graded exercise test with gas analysis to determine peak oxygen consumption (VO_{2peak}) (Vmax Series Software Version 12-3A, SensorMedics, Yorba Linda, CA, USA) performed on a bicycle ergometer (Ergoline GmbH - Ergoselect 200 P, Bitz, Germany) with