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Acute blood glucose responses on the second day of recovery from moderate vs. high intensity resistance exercise in women with type 2 diabetes

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Abstract

Resistance exercise (RE) can lower blood glucose in people with type 2 diabetes (T2D). However, greater clarity is needed regarding the RE intensity and time required for this acute response. Therefore, the aim of this study was to compare acute blood glucose responses on the second day of recovery from moderate vs. high-intensity RE in women with T2D. Twelve women with T2D (55.2 ± 4.0 years; 70.1 ± 11.4 kg; and 155.7 ± 3.3 cm) performed two experimental sessions seven days apart in a randomized order. For session 1: RE40% of one-repetition maximum test (1RM) and session 2: RE80%1RM, with 16 and 8 repetitions for each set, respectively, in 7 exercises with 3 circuits during 40min. Blood glucose was monitored for over 35h (first day: 24h and second day: 11h) every 5 minutes after each experimental session by the Continuous Glucose Monitoring System (*Guardian REAL-Time model*). *Student's t*-test showed no significant difference in blood glucose on the second day (11h) after RE40%1RM *vs.* RE80%1RM sessions [respectively, 161.3 ± 62.3 mg.dL^{-1} *vs.* 157.2 ± 41.9 mg.dL^{-1}; t (11) = 0.259; p = 0.800]. *Two-way* ANOVA for repeated measures showed that blood glucose responses every hour during recovery on the second day showed no significant differences between RE sessions [F (1.731, 19.039) = 0.688; p = 0.734]. We concluded that the acute blood glucose responses on the second day of moderate and high intensity RE did not differ among women with T2D.

Keywords: Resistance exercise. Diabetes. Blood glucose control.

INTRODUCTION

Sixteen million Brazilians have been diagnosed with diabetes mellitus, with Brazil holding the fifth position in the world ranking in relation to the number of cases[1]. The prevalence of diabetes mellitus is 23% in Brazilians of older ages and females are at greater risk[2].

Type 2 diabetes (T2D) represents 90% of all cases and is considered a chronic disease from defects in post-receptors of the insulin pathway, which causes decreased insulin sensitivity[1]. T2D is characterized by metabolic changes with high blood glucose levels and maintenance of the hyperglycemic state[3-4]. Chronic hyperglycemia can cause cellular apoptosis and lesions in organs and target tissues[5]. Hyperglycemia has been associated with arterial stiffness[6], endothelial dysfunction followed by arteriosclerosis[7], and cardiovascular diseases, especially in women[8,9], who are affected most by hospitalizations and have a larger risk of mortality resulting from diabetes mellitus[10].

Physical exercise has been strongly recom-

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mended as an effective tool in the blood glucose control of subjects with T2D3[11-17]. Evidence suggests that a single bout of aerobic[14,18] and resistance exercise (RE)[19-22] can promote blood glucose control within a period of up to 24 hours. However, the relationship of the RE intensity with the acute effects on the blood glucose control of patients with T2D is still conflicting, due to the duration and magnitude of the responses from the low, moderate, or high-intensity RE, as well as due to the external validity of the results obtained (purely laboratory vs. real-life conditions)[18-22].

Furthermore, to the best of our knowledge, no evidence of the acute effect of different RE intensities has been found for changes in blood glucose response for more than 24 hours in subjects with T2D. Such results could contribute to both the scientific community and patients with T2D who may benefit from the acute effects of high-intensity RE, which may still be questionable concerning relevant glycemic control[20,22]. In addition, the high-intensity RE could contribute in the medium and long-terms (training effect) to patients with T2D[16], who show a greater decline in muscle mass, muscle strength, and functional capacity with aging[23]. Thus, in order to clarify the understanding of late acute RE responses, the aim of this study was to compare acute blood glucose responses on the second day of recovery from moderate- vs. high-intensity RE in women with T2D. Although previous studies have demonstrated a distinction between the effects of moderate- vs. high-intensity RE on blood glucose concentrations in the first 24 hours[19,20], the hypothesis of the present study is that on the second day these differences will cease to exist, where the high-intensity RE session also starts to offer glycemic control for women with DM2.

METODOLOGY

Experimental Design

The design of this study included experimental sessions completed during two weeks of intervention. Blood glucose responses were analyzed for a period of 35 hours after performing RE sessions (40%1RM and 80%1RM) in a randomized order. For the first day (Day 1), the RE40%1RM or RE80%1RM tests were performed. On the second day (Day 2), the prolonged effect (11h) of the RE session in different intensities on the blood glucose concentration was analyzed as the aim of this study. For the analysis of blood glucose responses, the continuous glucose monitoring system was adopted.

Participants

Twelve postmenopausal women with T2D took part in the study according to pre-defined participation criteria, as follows: i) female; ii) diagnosed with T2D; iii) clinically stable, and; iv) age between 40 and 60 years. Exclusion criteria considered: i) use of exogenous insulin; ii) morbid obesity (body mass index >40 $kg.m^{-2}$); iii) decompensated blood glucose; iv) abnormalities on the electrocardiogram at rest with acute cardiac ischemia; v) heart disease, diabetic retinopathy proliferative or severe autonomic neuropathy; vi) upper or lower limb amputation; vii) present uncontrolled hypertension (systolic >160 mmHg and/or diastolic blood pressure >100 mmHg); viii) diabetic nephropathy (albuminuria ≥14 mg/L or >30 mg / 24h); ix) chronic kidney failure; x) exercise performance limitations due to joint/bone/skeletal muscle injury and; xi) smokers. This study was approved by the local Ethics Committee of Studies and Research from the Federal University of Vale do São Francisco (No. 0005/180814). Furthermore, this study is registered at www.clinicaltrials.gov (Nº. NCT02645448). The research was conducted according to the principles of the Declaration of Helsinki. The general characteristics of all participants are shown in Table 1.

Table 1 – Mean ± standard deviation of descriptive characteristics of the participants (n = 12). Petrolina, Pernambuco, Brazil, 2018.

General characteristics	
Age (years)	55.2 ± 4.0
Body mass (kg)	70.1 ± 11.4
Height (cm)	155.7 ± 3.3
Body mass index (kg.m$^{2(-1)}$)	29.0 ± 5.4
Fat percentage (%)	30.4 ± 5.9
Physical active level (min.wk^{-1})	120.2 ± 22.3
T2D diagnosis (years)	5.7 ± 3.7
Medication (n)	
Metformin	7 (58.4%)
Sulfonylureas	1 (8.3%)
Metformin and Sulfonylureas	3 (25.0%)
Diet only	1 (8.3%)
One-repetition maximal test (1RM)	
Bench press (kg)	26.7 ± 6.6
Leg extension (kg)	51.3 ± 15.1
Peck deck (kg)	19.8 ± 5.3
Leg curl (kg)	49.2 ± 11.7
Lat pull down (kg)	33.3 ± 7.5
Leg press (kg)	62.5 ± 18.3
Seated row (kg)	37.7 ± 8.3

Diet, Physical Activity, and Medication Control

All the participants received instructions in relation to food intake and the practice of daily physical activities in agreement with previous studies in our laboratory[19,20]. During the intervention, the participants receive a standardized breakfast with 285 kcal (45g carbohydrate, 6g proteins, and 9g fat). The participants were instructed to maintain the same diet during the two-week period of intervention and record for 35 hours their nutritional intake in a food diary following the previous procedures[19,20] and using the Brazilian Table of Food Composition[27]. The main meals (breakfast - 7:00 a.m. / 7:20 a.m., lunch - 12:00 p.m. / 02:00 p.m., and dinner - 06:00 p.m. / 8:00 p.m.) showed no significant differences between the experimental sessions (Table 2).

Procedures

Baseline Assessments

The participants performed a resting electrocardiogram to be able to start in experimental study procedures. All participants performed anamnesis about their historic health, physical exercise level[24], and anthropometric assessments with waist circumference, height, and body mass, and body mass index[25] and body fat percentage were also calculated[26].

All participants underwent a previous familiarization with the exercise protocol during three alternate days in accordance with previous studies[19,20]. After 48 hours, the 1RM test was performed (bench press, leg extension, peck deck, leg curl, lateral pull down, leg press, and seated row) in Evidence® (Cachoeirinha / RS – Brazil) and Physicus® equipment (Auriflama / SP – Brazil)[20].

Continuous Glucose Monitoring System (CGMS)

The CGMS Guardian REAL-Time model (Minimed Medtronic, Inc., Northridge, CA, USA), validated by previous studies[28,29], was installed in the participants to perform the test session (CONT40%1RM and CONT80%1RM). The glucose sensor (Sof-SensorTM) was inserted into the participant in agreement with previous studies[19,20] and according to factory instructions (Minimed Medtronic, Inc., Northridge, CA, USA). The participants were blinded to CGMS evaluations, which occurred every 5 minutes during the 35-hour intervention period (24h for the first day and 11h for second day). To analyze the results of the CGMS, data were exported and the signals were converted from the portable monitor (Guardian REAL-Time) to an online

program (CareLink; MedTronic)[29].

Study Procedures

A schematic overview of the study is shown in Figure 1. The blood glucose concentrations were analyzed in two experimental sessions, in which the same were separated into seven days and in a randomized order: Day 1: RE40%1RM and Day 2: prolonged effect of the RE session at 40%1RM), or Day 1: RE80%1RM and Day 2: prolonged effect of the RE session at 80%1RM. All procedures including the preintervention (Rest), intervention (RE sessions), and post-intervention occurred in accordance with previous studies in our laboratory[19,20].

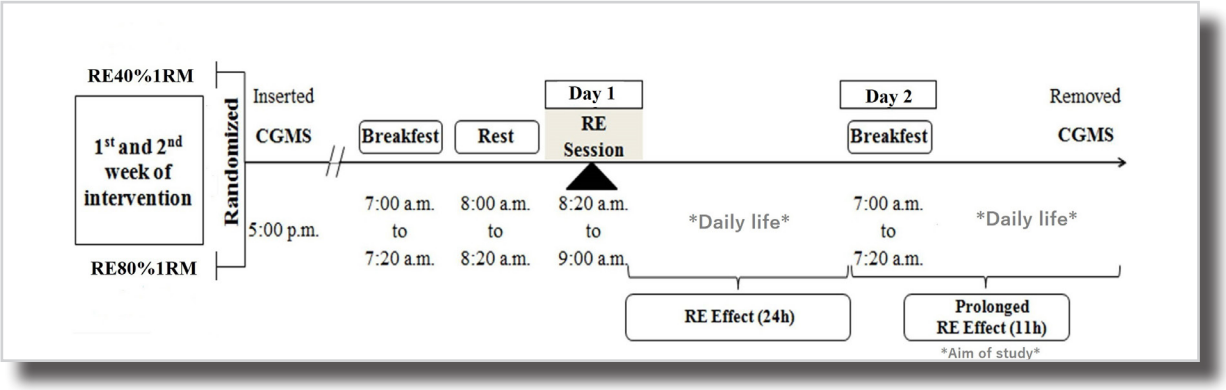

Figure 1 – Schematic overview of the study design. RE: Resistance Exercise; CGMS: Continuous Glucose Monitoring System.

Statistical Analyses

Data were presented as mean and standard deviation. The data normality was confirmed by the Shapiro-Wilk test. The blood glucose concentration values were used to determine the response throughout the post-experimental session period. Paired *Student t-test* was carried out to test the possible differences between the experimental conditions of Day 2 RE40%1RM *vs.* Day 2 RE80%1RM or an unpaired t-test to analyze Day 1 RE80%1RM vs. Day 2 RE80%1RM. Analysis of variance ANOVA *two-way* for repeated measures was carried out to test the possible differences on the second day between the experimental conditions (RE40%1RM vs. RE80%1RM) every hour for a period of 11 hours. The Bonferroni *Post-hoc* was used when the value of 'F' was considered significant for the identification of pairs of differences. The significance level was considered as $p < 0.05$. All analyses were performed using the SPSS software for Windows v. 22.0.

RESULTS

The general characteristics, use of medication, physical activity level, and strength performance of the participants are shown in Table 1. The daily food records showed no difference when comparing the experimental sessions (Table 2). Also, the blood glucose concentrations in the pre-intervention period of experimental sessions showed no significant difference with fasting glucose levels (Table 2).

Table 2 – Mean ± standard deviation of habitual energy intake (24 hours), and glucose concentrations before and after breakfast (n = 12). Petrolina, Pernambuco, Brazil, 2018.

	RE40%1RM	RE80%1RM	P value
Food intake diary			
Fat (g.day^{-1})	39.1 ± 16.4	36.5 ± 13.8	0.669
% intake	22.1 ± 8.2	22.2 ± 7.6	0.987
Carbohydrate (g.day^{-1})	236.2 ± 63.0	209.1 ± 38.9	0.219
% intake	59.1 ± 8.0	56.8 ± 5.9	0.431
Protein (g.day^{-1})	67.3 ± 21.4	65.3 ± 24.6	0.839
% intake	16.7 ± 2.9	17.4 ± 4.6	0.657
Energy intake (kJ.day^{-1})	6688.7 ± 1565.2	6184.0 ± 1094.6	0.370
Glucose concentration*			
Fasting glucose (mg.dL^{-1})	144.5 ± 34.5	148.1 ± 35.0	0.702
Rest glucose (mg.dL^{-1})	232.1 ± 14.8	234.5 ± 9.8	0.470

Source: research data. P value obtained by paired Student t-test. RE40%1RM and RE80%1RM = Resistance exercise at 40% and 80% of one-repetition maximum test; Fasting glucose and Rest glucose = Mean blood glucose concentrations before the breakfast at 7:00 a.m. and pre-intervention after the breakfast between 8:00 a.m. and 8:20 a.m.

Figure 2 shows the kinetics of the blood glucose concentration during different experimental sessions. The hyperglycemia level, which corresponded to blood glucose concentrations above 160 mg.dL^{-1}, was highlighted in both sessions and showed controlled values for RE80%1RM in this late period (second day) when compared to the first day of the same session (Day 1 RE80%1RM = 195.0 ± 17.0 mg.dL^{-1} vs. Day 2 RE80%1RM = 157.2 ± 9.4 mg.dL^{-1}; [t (392) = 23.777; p < 0.0001]).

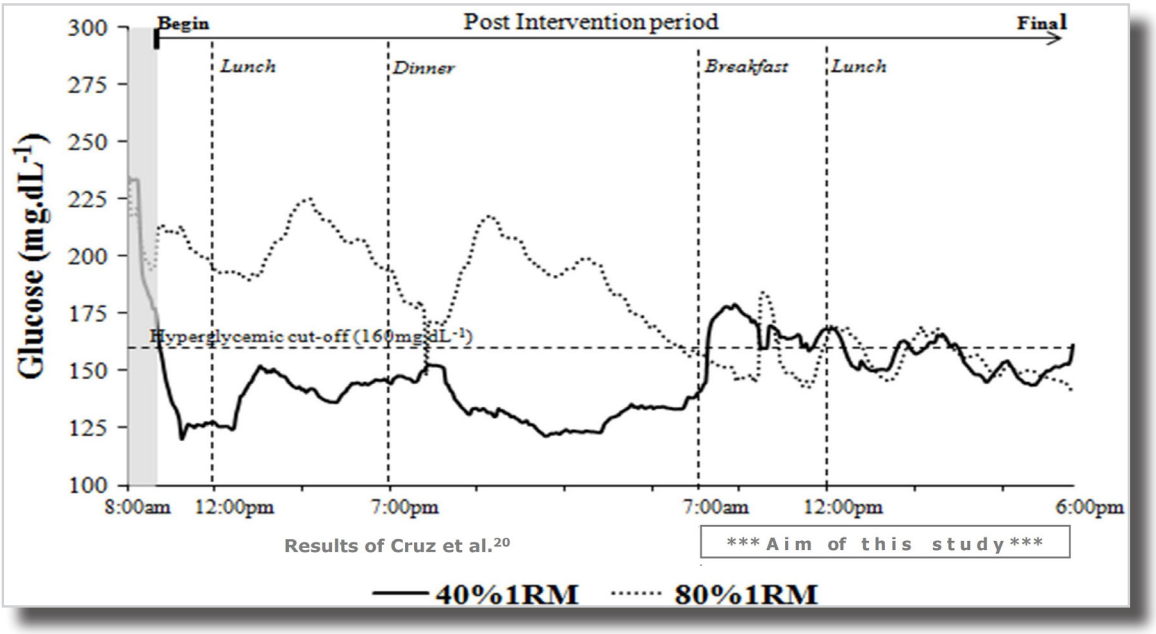

Figure 2 – Mean blood glucose concentrations (n = 12) throughout the 35-hour after resistance exercise period at 40% one-repetition maximum test (40%1RM) and 80%1RM. *Vertical dashed lines* indicate the time of lunch (12:00 a.m.), dinner (07:00 p.m.), and breakfast (07:00 a.m.). The hyperglycemia level[1], which corresponded to blood glucose concentrations above 160 mg.dL^{-1} was indicated by a *horizontal dashed line*. Unpaired *Student t-test* showed blood glucose control to second day of high-intensity RE (Day 1 RE80%1RM = 195.0 ± 17.0 mg.dL^{-1} *vs.* Day 2 RE80%1RM = 157.2 ± 9.4 mg.dL^{-1}; [t (392) = 23.777; p < 0.0001]).

Figure 3A shows the blood glucose concentration in entire of the second day in the RE40%1RM and RE80%1RM sessions in which there was no significant difference [t (11) = 0.259; p = 0.800] between sessions. Figure 3B shows the mean blood glucose concentration (second day) at each hour during the 11h analysis in the two sessions, in which there was no interaction time*session [F (1.731, 19.039) = 0.688; p = 0.734].

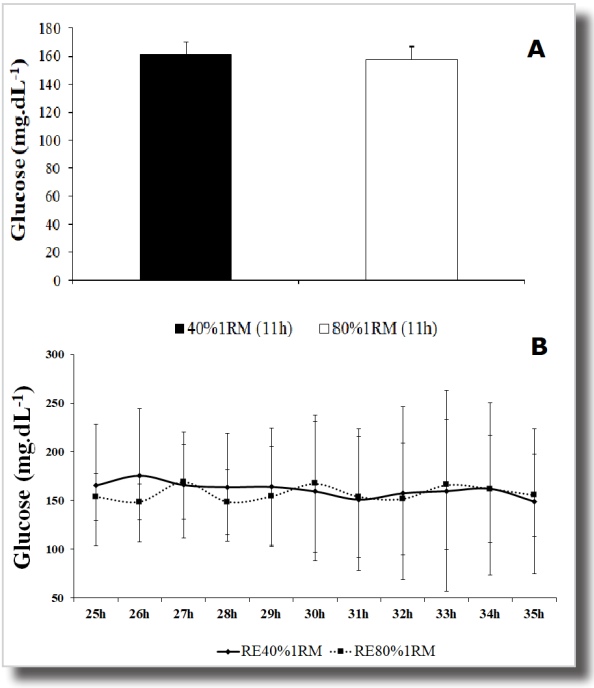

Figure 3 – Mean ± standard deviation of blood glucose concentration for 11 hours (A) and every hour (B) of evaluation on the second day in each RE session (n = 12). Paired *Student t-test* (A) and ANOVA *two-way* for repeated measures (B).

DISCUSSION

The objective of the present study was to compare acute blood glucose responses on the second day of recovery from moderate- vs. high-intensity RE in women with T2D. The main finding was that the blood glucose concentration during this later and prolonged period of 11 hours of daily life (second day) in both RE40%1RM and RE80%1RM sessions was not different (Figures 3A and 3B). Furthermore, curiously, blood glucose control occurred after the high-intensity RE (Figure 2).

In previous studies in our laboratory when comparing moderate-intensity RE (43%1RM) with the light RE (23%1RM), the light RE was more effective in the blood glucose control of patients with T2D in short recovery period (2 hours) and within a laboratory environment[22]. Besides, more recently it was possible to analyze in T2D individuals the acute effect of different intensities of RE by comparing moderate (40%1RM) and high-intensity RE (80%1RM) during a period of 24 hours[19,20]. Important blood glucose control occurred in the first 24h of the RE40%1RM session, which could not be verified in RE80%1RM and control sessions[20]. The mechanistic pathway discussed for non-glycemic control at 24 hours after high-intensity RE may be based on increased endogenous glucose production due to adrenergic stimulation and sympathetic activation[13,30,31]. Interestingly, the findings of the present study seem to suggest that the sleep period after RE80%1RM (after ~18 hours) has some importance since glucose concentration begins to decrease thereafter (Figure 2) and is maintained controlled and paired with the RE40%1RM session in the subsequent 11h and up to the 35h evaluation (Figure 2 and 3A-B). It is speculated that during the day after RE80%1RM (awake phase) the blood glucose production in patients with T2D has exceeded the uptake by muscle via an increased sympathetic drive to the liver[32]. On the other hand, when these patients went through their sleep period the reestablished neurophysiological setpoint occurred due to adjustments promoted by the suprachiasmatic nucleus[32]. As a result, rebalancing of glucose concentrations in the body may occur as presented after RE sessions performed in the present study (Figures 2 and 3A-B).

From a clinical point of view, these results are important since hyperglycemia can be more related to arterial stiffness[6] and atherosclerotic disease development[5,7] which increases the risk for cardiovascular events in T2D women[9]. In addition, the results strengthen the possibility of prescribing high-intensity RE sessions for the blood glucose control of T2D individuals. Considering that the sample was in a previous hyperglycemic state and T2D patients had blood glucose control only between 25h and 35h of the RE80%1RM session, we suggest that, in a previously hyperglycemic condition, low-intensity RE sessions should be performed in order to obtain normoglycemia state as we have shown in a previous study[20]. On the other hand, in the normoglycemia state, a T2D patient could already initiate a high-intensity RE session. This, in addition to maintaining the blood glucose maintenance in the subsequent 24 hours[20], could now promote neuromuscular and cardiovascular benefits (functional and structural) with the frequent accomplishment of these sessions[3,8,12,16]. Over time it would attenuate risk factors associated with disease and aging[23].

Although in the present study it is not possible to demonstrate such results, it is important to highlight a possible increased glucose uptake after the RE80%1RM session. Koopman *et al.*[33] found an improvement in insulin sensitivity in healthy men in the 24h following high-intensity RE (75%1RM). Fenicchia *et al.*[21] investigating high-intensity RE in women with T2D found an improvement in the integrated blood glucose concentration. However, in agreement with the aforementioned studies, even with the possible increased blood glucose uptake in the RE80%1RM session due to the greater requirement of intensity in the effort[21,33], it is also highlighted the possible excessive blood glucose endogenous production during the day[13,30,31] and especially in the ~18 hours after high-intensity RE[32]. On the other hand, Gordon *et al.*[34] found no improvement in insulin sensitivity in T2D patients from 24 to 78 hours after performing moderate to high-intensity RE (45%, 60%, and 75%1RM). These results are influenced by the protocol chosen, which recommended only exercises for lower limbs. The methodology of the present study involved the main muscle groups for both upper and lower limbs[20].

The practical application of these results may be useful for T2D individuals with blood glucose concentration within normal limits before an exercise session. It is recommended to perform a single RE session with three circuits (each circuit with 8 repetitions in seven exercises to upper and lower limbs) at 80%1RM intensity. The recovery period between circuits should be 120 seconds and between exercises should be 90 seconds in which the participant should change the exercise, performing them in an alternating fashion (preferably). This intervention may be effective in lowering blood glucose concentration between 25h and 35h after the RE session in T2D women with a previous hyperglycemic state. However, we suggest this exercise intensity, especially for the patient with T2D in normoglycemia state, who would be maintaining the blood glucose control in the subsequent 24 hours[20] and 35 hours (present study) after high-intensity RE, who would also benefit from additional neuromuscular gains (functional and structural) with the frequent accomplishment of these sessions. Finally, although this high RE intensity is considered secure in terms of cardiovascular and endocrine stress when the subjects are clinically controlled (controlled blood glucose and controlled blood pressure), a previous medical screening including an orthopedic, cardiovascular, and metabolic evaluation is strongly recommended.

One limitation of the present study was the lack of standardization in food intake during the remaining of the day, since this study only standardized the breakfast for the participant with T2D during the experimental sessions. On the other hand, there is the external validity of our results, since the participants with T2D maintained their daily dietary routines, as shown in the statistical analysis of the participants' food records during the experimental sessions (Table 2).

CONCLUSION

We concluded that there is no difference in the blood glucose concentration of postmenopausal women with T2D on the second day of recovery of moderate- and high-intensity RE (between 25 and 35 hours). Furthermore, the blood glucose control in women with T2D also occurred after late recovery from the high-intensity RE.

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Author statement CRediT

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