



# Insulin-Associated Weight Gain in Type 2 Diabetes Is Associated With Increases in Sedentary Behavior

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The insulin therapy-mediated weight gain in patients with type 2 diabetes (T2D) may relate to altered physical activity patterns (1). In this study, we examined the hypothesis that initiation of insulin therapy would be associated with an increase sedentary behavior (i.e., sitting time) and lower low-, moderate-, and vigorous-intensity physical activity, which would subsequently relate to weight gain.

We included 40 T2D patients who started insulin therapy and followed these patients for a period of 12 months. Patients were randomly selected from one university hospital, three non-university teaching hospitals, and four primary care practices. The decision to start insulin treatment was at the discretion of the responsible physician and was always based on failure of glycemic control while on oral glucose-lowering agents and diet. Measurements were performed before and 6 months and 12 months after initiation of insulin therapy. We examined body weight, waist-to-hip circumference, fasting glucose, and HbA<sub>1c</sub> using standardized procedures. Free-living daytime physical activity was objectively measured (SenseWear Pro3 Armband, BodyMedia, Pittsburgh, PA) (2). We examined 1) time (hours/day) spent in sitting (<1.5 METs), low-intensity physical activity (LPA) (2.1–3.0 METs), and

moderate- to vigorous-intensity physical activity (MVPA) (>3.0 METs); 2) steps per day; and 3) sit-to-stand maneuvers (transition from ≥5 min sitting to LPA). Results are expressed as mean ± SD.

Over 12 months, body weight increased  $2.9 \pm 4.5$  kg ( $P < 0.05$ ). This observation is largely in line with earlier findings (3). Furthermore, fasting glucose and HbA<sub>1c</sub> decreased over 12 months (both  $P < 0.05$ ). Interestingly, we found an increase in sitting time and a decrease in LPA but no change in MVPA (Fig. 1A–C). Number of steps ( $7,854 \pm 3,936$  to  $6,060 \pm 3,022$ ) and sit-to-stand maneuvers ( $20 \pm 5$  to  $18 \pm 6$ ) significantly decreased (both  $P$  values  $< 0.05$ ). These findings show an increase in sedentary behavior rather than a decrease in physical activity (including exercise time) that occurs simultaneously with an increase in body weight after initiation of insulin therapy. Because sedentary behavior replaced LPA, lower energy expenditure may relate to our observation (4). However we found no relationship between changes in energy expenditure and weight gain ( $r = -0.195$ ,  $P = 0.227$ ). Excessive caloric intake is less likely to explain our observation, as food diaries revealed no increase in caloric intake ( $1,721 \pm 839$  to  $1,460 \pm 367$  calories/day,  $P = 0.074$ ).

T2D patients with BMI  $< 30$  kg/m<sup>2</sup> (aged  $64 \pm 10$  years) showed less sitting time ( $P = 0.012$ ) and more LPA ( $P = 0.012$ ) than those with BMI  $\geq 30$  kg/m<sup>2</sup> (aged  $57 \pm 9$  years). Surprisingly, upon insulin therapy, BMI and waist circumference increased in subjects with BMI  $< 30$  kg/m<sup>2</sup> but not in those with BMI  $\geq 30$  kg/m<sup>2</sup>. Similarly, patients with BMI  $< 30$  kg/m<sup>2</sup> but not those with BMI  $\geq 30$  kg/m<sup>2</sup> demonstrated an increase in sitting time and a decrease in energy expenditure and steps/day (data not shown). We found significant, positive relationships between changes in weight and waist circumference versus sitting time (Fig. 1D–E). This fits with previous work in populations without diabetes, where an increase in sedentary behavior was related to weight gain (5). T2D patients with BMI  $\geq 30$  kg/m<sup>2</sup> did not demonstrate these relationships ( $r = -0.186$  and  $-0.041$ ,  $P = 0.474$  and  $0.879$ , for weight and waist circumference, respectively). A potential explanation for these unexpected between-group differences may relate to a ceiling effect in sedentary behavior in patients with BMI  $\geq 30$  kg/m<sup>2</sup>. Indeed, the average sitting time of 12.5 h makes it practically difficult to further increase sedentary behavior.

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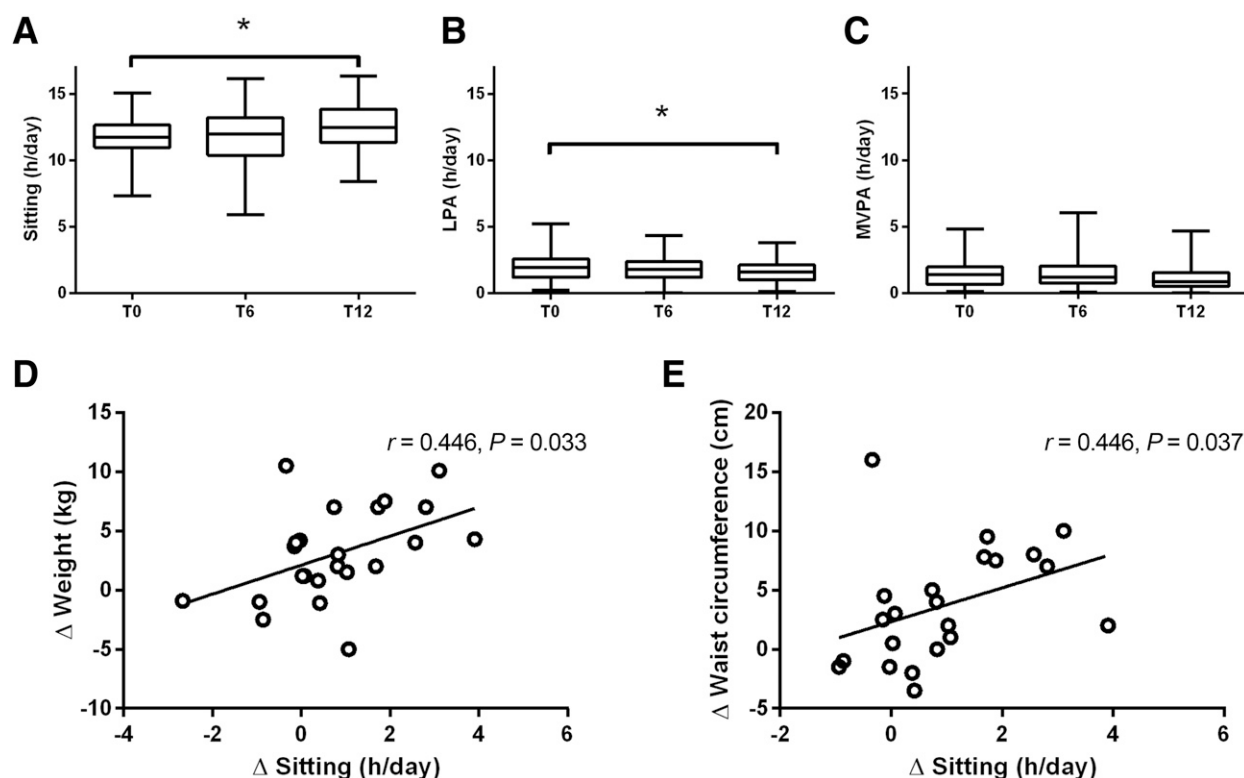
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**Figure 1**—A–C: Physical activity patterns in T2D patients at baseline (T0) and after 6 months (T6) and 12 months (T12) of the start of insulin therapy, where patterns are presented as sitting (A), LPA (B), and MVPA (C). The plot elements are presented as follows: the length of the box represents the interquartile range (the distance between the 25th and the 75th percentiles), the horizontal line in the box interior represents the median, and the vertical lines issuing from the box extend to the minimum and maximum values of the variables. \*Post hoc analysis significantly different from T0 at  $P < 0.05$ . D and E: Spearman correlations of change in sitting time between baseline and 12 months of insulin therapy and weight gain (D) and waist circumference (E) among T2D patients with baseline BMI  $< 30$  kg/m<sup>2</sup>. Spearman rank correlation coefficients ( $r$ ) are shown for each correlation. Solid lines indicate linear regression function.

We observed that the initiation of insulin therapy was associated with an increase in sedentary behavior and limited changes in MVPA. This suggests that increased sedentary behavior, especially in nonobese T2D patients, may contribute to body weight gain after initiation of insulin therapy. These findings suggest that sedentary behavior assessment and intervention may be needed in T2D management.

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