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**Section:** Original Research

**Article Title:** Physical Activity Levels of Adolescents With Type 1 Diabetes

**Authors:** Valderi Abreu de Lima[1, 3]; Luis Paulo Gomes Mascarenhas[3,4]; Juliana Pereira Decimo[3]; William Cordeiro de Souza[5]; Anna Louise Stellfeld Monteiro[3]; Ian Lahard[2]; Suzana Nesi França[3]; and Neiva Leite[1]

**Affiliations:** [1]Federal University of Paraná-Department of Physical Education, Paraná , Brazil. [2]Faculty of Education, Health and Wellbeing, Institute of Sport, University of Wolverhampton, United Kingdom. [3]Federal University of Paraná - Unit of Pediatric Endocrinology, Paraná , Brazil. [4]State University Midwest-UNICENTRO, Brazil. [5]University of Contestado-UnC- NEAF, Santa Catarina, Brazil.

**Journal:** *Pediatric Exercise Science*

**Acceptance Date:** November 26, 2016

**Running Head:** Physical activity in T1D



**DOI**: http://dx.doi.org/10.1123/pes.2016-0199

“Physical Activity Levels of Adolescents With Type 1 Diabetes” by Abreu de Lima V et al. ]
*Pediatric Exercise Science*


Valderi Abreu de Lima[1, 3]; Luis Paulo Gomes Mascarenhas[3,4]; Juliana Pereira Decimo[3]; William Cordeiro de Souza[5]; Anna Louise Stellfeld Monteiro[3]; Ian Lahard[2]; Suzana Nesi França[3]; Neiva Leite[1]

1-Federal University of Paraná-Department of Physical Education

2-Faculty of Education, Health and Wellbeing, Institute of Sport, University of Wolverhampton

3-Federal University of Paraná - Unit of Pediatric Endocrinology

4-State University Midwest-UNICENTRO

5-University of Contestado-UnC- NEAF

**Abstract**

The aim of this study was to evaluate the level of physical activity and cardiorespiratory fitness in teenagers with type 1 diabetes mellitus (T1D) in comparison with healthy scholar participants. Total of 154 teenagers (T1D=45 and CON=109). Height, weight, cardiorespiratory fitness (VO2max), and the level of physical activity by the Bouchard's Physical Activity Record were measured, and glycated hemoglobin (HbA1c) in T1D. The VO2 max was lower in the T1D (38.38 ± 7.54) in comparison with the CON (42.44 ± 4.65; $p<0.05$). The VO2max had correlation with the amount of time of moderate-to-vigorous physical activity (r= 0.63; p= 0.0001) and an inverse correlation with sedentary activities (r= -0.46; p= 0.006). In the T1D the levels of HbA1c had an inverse correlation with the amount of time of moderate-to-vigorous physical activity (r= -0.34; p= 0.041) and correlation with the BMI z-score (r= 0.43; p= 0.017). Only 37,8% of the participants in the T1D reached the adequate amount of daily moderate-to-vigorous intensity physical activity, in the CON 81,7% reached the WHO’s recommendation. Conclusion: T1D had less cardiorespiratory capacity then healthy controls, the teenagers of T1D with lower BMI z-score and that dedicated a greater time in moderate-to-vigorous intensity physical activity demonstrated a better glycemic control.

## Introduction

In patients with type 1 *Diabetes Mellitus* (T1D), physical activity can have complex consequences on the regulation of blood glucose. The magnitude of these effects is largely dependent on the intensity, duration and type of activity, in addition to other factors such as insulin regimens, food intake and blood glucose levels prior to activity (8, 21, 10).

Regular physical activity is associated with acute and chronic health benefits, such as improved glycemic control, insulin sensitivity, body composition, quality of life, and in the long term, reduced risk of cardiovascular complications (11). The International Society for Pediatric and Adolescent Diabetes (ISPAD) (18) advocates the importance of encouraging children and adolescents to be physically active and less sedentary to help control their body weight and mitigate increased cardiovascular risk. Therefore, physical activity is one of the pillars in the treatment of diabetes and in the maintenance of a healthy lifestyle (30). However, fear of hypoglycemia and difficulty with glycemic control, resulting from inadequate alimentary adjustment and use of exogenous insulin, are frequently reported as barriers to becoming more active by children and adolescents with T1D (11).

In the last decades, changes in people's lifestyle have impacted on the youth population (8). Currently, an estimated 80% of adolescents do not achieve public health guidelines for recommended levels of physical activity (i.e. 60 min per day or more of moderate to vigorous physical activity (38), and more than half of boys and girls worldwide spend 2 h or more per day watching television (14). Despite the substantial evidence supporting the beneficial effect of physical activity, adolescents with T1D often do not achieve the recommended physical activity level and are sometimes less active than their healthy peers (20).

Patients with T1D for a safe practice of physical activity should have pre-exercise glucose levels below 14 mmol/L (250 mg/dL) and or ketonemia (<0.5 mmol/L) (30). The maintenance of a good glycemic control is associated with the reduction of risk factors of cardiovascular diseases and the incidence of chronic complications, such as diabetic nephropathy, retinopathy and neuropathy (12). Regular physical activity and improved cardiorespiratory fitness can play an important role in the prevention of these complications (34).

Previous studies have demonstrated a direct association between glycemic control and physical activity (16, 31) and cardiorespiratory fitness (11). Aman and colleagues (1) found that a reduction of sedentary activities through an increase in physical activity was associated with improved glycemic control and reduced levels of HbA1c. Hence, it is important to diagnose the physical activity level and cardiorespiratory fitness of adolescents with T1D, once the engagement in regular physical activities is a part of their treatment. It is necessary to have more information about the daily reality and lifestyle of the people with T1D so they safely engage in physical activity and therefore, receive the associated beneficial adaptations. Therefore, the present study aimed to compare the physical activity levels of adolescents with T1D to those of a healthy adolescent control group, as well to investigate the relationship between the physical activity level and cardiorespiratory fitness and glycemic control.



## Materials and methods

The present a case-control study included 154 adolescents divided in two groups. The first group consisted of patients diagnosed with T1D (N = 45, Boys= 25, Girls= 20) at least six months before the study and that attended to the diabetes clinic of the Pediatric Endocrinology Unit of Clinical Hospital federal of Paraná (Curitiba-Paraná, Brazil), while the second, was a control group (N =109, Boys= 58, Girls= 51) of healthy adolescents recruited from a public school from the city of Curitiba-PR. The adolescents were aged between 10 and 15 years, and had no other comorbidities. The participants and their parents or legal guardians signed an informed consent term, as in the research project. The study was approved by ethics committee on human research of the Clinical Hospital of Federal University of Paraná.

Stature was measured using a portable vertical stadiometer (WCS®, Brazil), scaled at 0.1 cm. Weight was evaluated via a portable digital scale (Filizola®, Brazil), with 100 grams resolution. To assess the nutritional status, the BMI z-score was calculated by the WHO Antro Plus 10.4 program, based on sample mean.

To evaluate cardiorespiratory fitness (maximal oxygen uptake, $VO_2$ max), participants were assessed via the modified Balke protocol with cycle ergometery[(15 )]and open circuit direct calorimetry, via the K4b2 gas analyzer Cosmed®. The test was initiated at a load of 25 W and cadence of 50 rpm, and the load was then increased by 25 W every three minutes until the individual reached his/her maximum heart rate (220-age) (5), or when he could not maintain the required cadence at a given load.

Physical activity levels were measured by self-report with the Bouchard's Physical Activity Record (BAR) questionnaire (6). BAR registers the daily activities of the individual that are at least 15 minutes duration over three days of a week (two from week days and one from the weekend). By recording the prevailing daily activities of the child every 15 minutes, it is possible to estimate the total daily energy expenditure per kg body weight (kcal/kg/day) as well as the level of habitual physical activity by means of the 3 days selected (13).

Physical activity levels were analyzed and the time (minutes) dedicated to the diverse activities according to categories 1 and 9, was classified as: time sleeping (SLEEP) category 1, time dedicated to sedentary activities (SED) category 2, time dedicated to light-intensity physical activities (LIGHT PA) category 3, 4 and 5. And time dedicated to moderate-to-vigorous intensity physical activities (MVPA) categories 6, 7, 8 and 9.

We also recorded the proportion of participants that reached the WHO’s minimum recommendation of 60 min of daily MVPA (38). The patients with T1D had their levels of glycated hemoglobin (HbA1c) measured, via immunoturbidimetric TurbiClin test, to verify glycemic control. Blood samples were taken via venous puncture after 12 hours of fasting; the blood was then stored in a test tube and taken for chromatographic analysis.

All data were analyzed using the statistical program SPSS *for Windows* version 22.0. Sample characterization descriptive statistics were reported as mean and standard deviation, and the normality was verified via the Shapiro-Wilks test. For the between groups comparison of variables, the *t* Student test was used for the normally distributed variables, and the U of Mann Whitney test for the non-normally distributed variables. Pearson correlation coefficients were used to investigate associations between HbA1c, physical activity level (kcal/kg/day), sleep (hours/day), sedentary activities (min/day), MVPA (min/day), $VO_2$ max (ml/kg/min), and BMI z score of the T1D patients. Participants were classified as active (≥300 min of MVPA per week) and non-active (<300 min of MVPA per week) according to the WHO recommendation (38), and differences between the proportion of active/non-active adolescents with T1D versus healthy controls were analyzed via for chi-square tests. For all analyses, significance was defined as $p < 0.05$.



## Results

There were no significant differences for age or for the variables weight, height and BMI z-score standardized between healthy adolescents and those with T1D. The sample characteristics are shown in table 1.

Physical activity levels are shown in table 2. Physical activity level (Kcal/kg/day), sleep duration (hours/day), LIGHT PA (min/day), MVPA (min/day) and $VO_2$ max were all significantly higher in healthy controls compared to adolescents with T1D, whereas SED (min/day) was significantly higher in the T1D group compared to control.

Pearson correlation coefficients between HbA1c, physical activity levels (kcal/kg/day), time of sleep, time of SED and time of MVPA, VO2max and BMI z-score for the T1D group are presented in Table 3. Significant positive associations were found between HbA1c and BMI, physical activity (kcal/kg/day) and $VO_2$ max and MVPA (min/day) and $VO_2$ max, whereas negative associations were observed for HbA1c and MVPA (min/day), physical activity (kcal/kg/day) and sedentary activities, sleep and sedentary activities, sedentary activities and MVPA (min/day), and sedentary activities and $VO_2$ max.

There was a significantly lower proportion of adolescents with T1D that reach the WHO recommendations for physical activity (i.e. ≥300 min of MVPA per week) and the control group (51.1%, n = 23 vs. 88.2%, n = 105, respectively; p= 0.0001) (Fig 1). There was a significant difference between the proportion of participants with T1D with an HbA1c above and below 7.5% in those who were active (i.e. ≥300 min of MVPA per week) compared to those who were not ($\chi^2$= 4.29; p= 0.038). Of the 23 adolescents with T1D who reached the 300 minutes of weekly MVPA, eight (34.8%) had good glycemic control, with HbA1c levels of under 7.5%, whereas, only two (9.1%) of the non-active adolescents with T1D had HbA1c levels under 7.5% (Fig 2).

## Discussion

The current study aimed to compare the level of physical activity of adolescents with T1D to healthy adolescents, as well to investigate the relationship between the physical activity level and cardiorespiratory fitness and glycemic control.

Physical activity levels were different between groups, with the adolescents with T1D reporting lower daily energy expenditure (kcal/kg/day), which may be associated with the significantly greater MVPA levels of the healthy controls in comparison with the T1D group. The time dedicated to sleep was greater in the healthy controls in comparison with the T1D (11 vs. 9 hours), could be related to the greater daily caloric expenditure of the healthy adolescents, as well as the fear of nocturnal hypoglycemia in people with T1D that might negatively influence the sleep quality of our adolescents with diabetes (24). The fear of nocturnal hypoglycemia can also have a negative effect on the quality of life of patients with T1D and their families (19).

Time spent in SED was significantly different between groups, with the adolescents with T1D reporting more time engaged in this kind of activity than their healthy counterparts (10.5 vs. 8.6 hours). This observation is consistent with that of Maggio et al. (22), who observed that teenagers with T1D were less active than teenagers without the disease. However, in contrast, Raile et al. (28) evaluated the time dedicated to sports activities and physical activity of adolescents with diabetes versus non-diabetic controls, and found no significant between-group differences.

Another study classified the time dedicated to different intensities of physical activity performed by children and adolescents with T1D (23). Similar to the current study, the authors (23) observed that the time spent in sedentary activities (e.g. watching television, playing electronic games, using cellphones or computer) was high, and greater than the time spent in light intensity physical activities (e.g. staying stand up without moving, activities of daily living, light chores, walks with velocity ≤4 km/h) (23). Valério et al. (36) observed that in 138 children and adolescents with T1D and 269 healthy teenagers, engagement in sports and MVPA was lower in adolescents with T1D compared to those who were healthy. The lower physical activity observed in the individuals with T1D could explain our finding of lower cardiorespiratory fitness in the T1D group versus healthy control (38 vs. 42 ml/kg/min). The mean $VO_2$ max values found in the T1D group were below the expected values for teenagers (39 to 50 ml/kg/min) (3). $VO_2$ max is an important marker for the cardiovascular condition and a predictor of associated comorbities (2). Better levels of cardiorespiratory fitness results directly in the increase of maximum cardiac output and improvements in the functional capacity of the heart (2). Knowledge of an individual's $VO_2$

max is advantageous as it allows health professionals to personalize exercise prescription and evaluate the effects of training programs (4).

The adolescents with T1D from this study presented with inadequate glycemic control as indicated by mean levels of HbA1c of 9 ± 2% (18, 17). HbA1c levels over 7% and constant hyperglycemias represent on increased risk of long terms complications (37). The occurrence of chronic hyperglycemia can predict future micro and macrovascular complications and is directly related to the levels of HbA1c (21). According to Nathan et al. (25) HbA1c values of over 10.4% are associated with a seven-fold increased risk of death due to cardiovascular complications in adults (26).

The HbA1c levels of our adolescents with T1D were inversely correlated to the MVPA, and positively correlated with the BMI z score. Taken together these data suggest that those who spent more time performing MVPA also had greater glycemic control. Greater $VO_2$ max values were associated with higher MVPA and lower SED. Increasing the amount of MVPA and reducing time spent performing SED is expected to improve $VO_2$ max and result in a greater aerobic capacity, which may help to reduce the risk of death from cardiovascular diseases (33).

Despite the proposed health benefits associated with regular performance of at least 60 minutes of daily MVPA, the majority of adolescents with T1D did not meet this recommendation (29, 15). We observed that 62% of the adolescents with T1D did not reach the WHO’s recommendation, in contrast with 82% of the healthy adolescents achieving this recommendation. Similarly, Schweiger, et al (32) found that only 5% of teenage girls with T1D met the recommended level of physical activity.

When adolescents were analyzed separately, we found that a higher proportion of CON teenagers again, met the recommended physical activity guidelines than the T1D (88% and 51%, respectively, figure 1). In support of our finding, a previous case-control study analyzed 138 children and adolescents with T1D, and observed that children and adolescents with T1D tended to spend less time performing physical activity than their non-diabetics counterparts (36).

The fear of hypoglycemia reported by patients with T1D (24), may potentially help explain the lower MVPA in our group with T1D. This fear is an important limiting factor to the regular practice of physical activity for patients with T1D that prevents them from experiencing benefits of exercise. Even though physical activity is associated with numerous physiological and psychological benefits (27), it can trigger hypoglycemia during or several hours after the practice (35). During physical activity, muscles begin to consume a greater amount of glucose for energy metabolism, and low level of insulin in circulation that could diminish hepatic gluconeogenesis, increasing the risk of hypoglycemia (24). Hypoglycemia can negatively impact inflammatory markers and endothelial function when acute and mild, and can result in loss of consciousness, seizure, coma and even death in severe cases (9).

Of the adolecents with T1D that reached the recommended 300 minutes of weekly physical activity, more than a third (35%) had good glycemic control with HbA1c lower than 7.5%. However, one in 10 of the patients with T1D that failed to achieve the WHO’s physical activity recommendation had HbA1c’s levels under 7.5%. These data suggest that adolescents with T1D with higher levels of MVPA had better HbA1c values, suggesting that physical activity may help improve glycemic control. Therefore, it may be important that patients with T1D engage more in MVPA to help in the maintenance of the glycemic control.

Despite evidence that regular physical activity can be considered as one of the pillars of treatment of T1D, and is associated with improved lipid profile and metabolic control and reduced risk of future complications (36, 3), the results of the present study show that this, at least in our sample, is not a commonly adopted practice by the majority of the adolescents with T1D. This is concerning because sedentary children and adolescents tend to become sedentary adults (7).

This current study presents some limitations, such as the absence of control of some confounding variables (e.g. puberal maturation, nutritional quality, presence of barriers to physical activity), use of a convenience sample, measurement of physical activity via self-report. Further studies should aim to investigate the determinants of physical activity in adolescents with T1D in order to better implement effective interventions aimed to increase the physical activity and cardiorespiratory fitness levels of patients with diabetes.

## Conclusion

The adolescents with T1D had lower physical activity and cardiorespiratory fitness levels than their healthy peers. About two thirds of the patients with T1D did not reach the minimum recommendation of 60 minutes a day or 300 minutes a week of physical activity, compared to the majority of healthy controls who met this recommendation. Adolescents with a lower BMI z-score and who dedicated more time to MVPA also had improved glycemic control. Our findings support the notion that individuals with T1D should be encouraged to engage in regular MVPA, increase their daily energy expenditure and reduce sedentary time.

## Acknowledgments:

We thank the support with research funding and scholarships to CNPq and CAPES.

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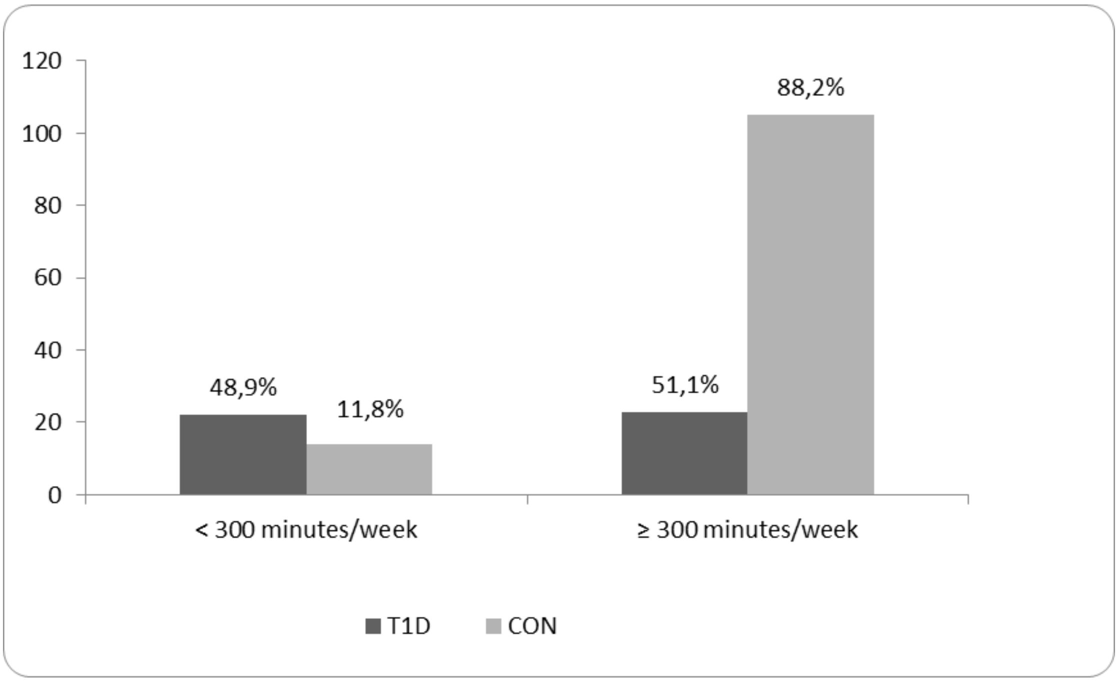


**Figure 1:** Percentage of adolescents above and below the WHO recommended 300 minutes a week of moderate-to-vigorous intensity physical activity from the T1D group versus the healthy controls (CON)

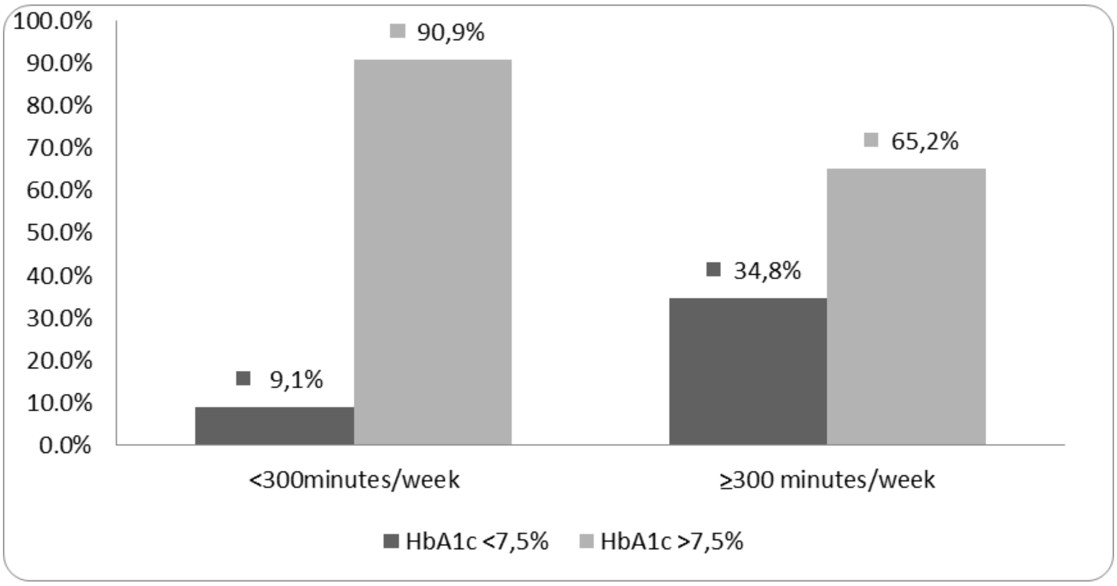


**Figure 2:** Percentage of adolescents with T1D and an HbA1c above and below 7.5% who achieved the 300 min/week of moderate to vigorous physical activity WHO recommendation versus those that did not.

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**Table 1:** Sample characteristics.

| | T1D | CON | Statistic | P |
|---|---|---|---|---|
| **N** | 45 | 119 | - | - |
| **AGE** | 12.36 ± 1.52 | 11.64 ± 0.73 | U | 0.744 |
| **WEIGHT-Z** | 4.12 ± 0.07 | 5.79 ± 1.03 | U | 0.824 |
| **HEIGHT-Z** | 2.70 ± 0.63 | 1.83 ± 0.57 | T | 0.085 |
| **BMI-Z** | 0.43 ± 0.95 | 0.31 ± 1.41 | T | 0.631 |
| **HbA1c%** | 9.15 ± 1.61 | - | - | - |

**Key** = T = T of Student Test; U = Mann Whitney Test; BMI-Z = Body mass index Z-score

**Table 2:** Physical activity level (PAL) and time dedicated to different intensity activities

| | T1D | CON | P* |
|---|---|---|---|
| **PAL (kcal/kg/day)** | 38.85 ± 4.22 | 40.65 ± 3.97 | 0.01* |
| **SLEEP (hours/day)** | 9.41 ± 1.42 | 10.89 ± 1.55 | 0.001** |
| **SED (min/day)** | 631.44 ± 129.58 | 514.27 ± 113.17 | 0.001** |
| **LIGHT PA (min/day)** | 174.89 ± 93.19 | 210.09 ± 89.33 | 0.03* |
| **MVPA (min/day)** | 68.78 ± 34.11 | 118.85 ± 68.69 | 0.001** |
| **$VO_2$ max (ml/kg/min)** | 38.38 ± 7.54 | 42.44 ± 4.65 | 0.001** |

* T Student Test P < 0.05;

** T Student Test P < 0.01;

**Key:** PAL = Physical activity level; SLEEP = Sleep time; SED = time spent on sedentary activities, LIGHT PA = light physical activity; MVPA = Time spent on moderate-to-vigorous intensity activity; and $VO_2$ max = maximal oxygen uptake (ml/kg/min).

**Table 3:** Pearson correlation coefficients (*r*) of the patients with type one diabetes mellitus.

| | HbA1c | PAL | SLEEP | SED | MVPA | $VO_2$ max | BMI-Z |
|---|---|---|---|---|---|---|---|
| **HbA1c** | 1.00 | -0.32 | -0.01 | 0.13 | -0.34* | -0.21 | 0.43* |
| **PAL** | | 1.00 | -0.06 | -0.54** | 0.90** | 0.60** | -0.04 |
| **SLEEP** | | | 1.00 | -0.64** | 0.16 | 0.21 | 0.14 |
| **SED** | | | | 1.00 | -0.49** | -0.46** | -0.13 |
| **MVPA** | | | | | 1.00 | 0.63** | -0.03 |
| **$VO_2$ max** | | | | | | 1.00 | -0.27 |
| **BMI-Z** | | | | | | | 1.00 |

* $P < 0.05$;

** $P < 0.01$;

**Key:** HbA1c= Glycated hemoglobin; PAL= Physical activity level (Kcal/Kg/day); SLEEP = Sleep time; SED = time spent on sedentary activities; MVPA = Time spent on moderate-to-vigorous intensity activities; $VO_2$ max = Maximal oxygen consumption (ml/kg/min); BMI-Z = Body mass index Z-score;