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Seasonal differences in physical activity, sedentary behaviour, and sleep patterns in people with type 1 diabetes in Kuwait

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ABSTRACT

Aims: The main aim of the current study was to measure physical activity, sedentary behaviors and sleep levels across the different seasons in people with type 1 diabetes in Kuwait.

Methods: A prospective cross-sectional study was conducted from August 2021 to September 2022. Physical activity and sleep metrics were measured over a 7-day period with a wrist-worn accelerometer (GENEActiv). Overall physical activity was measured as a Euclidean Norm Minus One in milli gravitational units (mg). Accelerometer metrics were compared across the seasons and between the sex.

Results: A total of 784 people with type 1 diabetes participated. Mean daily physical activity was 25.2 mg (SD = 7.3). Seasonal differences were seen in overall physical activity ($p = 0.05$), inactivity ($p = 0.04$), light activity ($p = 0.001$), the intensity gradient ($p = 0.001$) and sleep efficiency ($p = 0.02$). Poorer metrics were generally seen in Spring and Summer. Overall physical activity, moderate and vigorous physical activity, and inactivity were significantly higher in males compared to females ($p \leq 0.02$). Females had a longer sleeping duration ($p = 0.02$), and higher sleep efficiency ($p = 0.04$) and light physical activity ($p = 0.01$). Overall physical activity and the intensity gradient were negatively associated with HbA1c (both $p = 0.01$).

Conclusions: Physical activity levels were generally low and sleep poor in people with type 1 diabetes in Kuwait and these varied by sex and season. The current data are useful to target and develop interventions to improve physical activity and glycemic control.

1. Introduction

Worldwide there are currently 537 million adults (20–79 years) and 73 million in the Middle East and North Africa region living with diabetes, with about 25 % of adults living with diabetes in Kuwait [1]. About 5–10 % of people with diabetes have type 1 diabetes. The prevalence of type 1 diabetes is on an upward trajectory, and this condition results in an increase in the risk of microvascular and macrovascular diseases, such as neuropathy, nephropathy, retinopathy, coronary vascular disease (CVD), peripheral arterial disease and cerebrovascular disease [2,3]. In fact, people with type 1 diabetes have 5–10 times higher risk of having a CVD event [4], with the risk higher still if onset occurs at a younger age [5]. At the age of 20 years, the life expectancy of people with type 1 diabetes is around 12 years lower, than people without type 1 diabetes, with around 1/3 of this excess risk due to cardiovascular disease [6]. The prevalence of type 1 diabetes varies between countries with the incidence particularly high, and rising, in Kuwait [7].

Regular physical activity is an important determinant of health and is recommended for people of all ages with type 1 diabetes to improve, amongst other benefits, cardiovascular fitness and bone-health [8–10]. For example, in people with type 1 diabetes, higher physical activity levels are associated with a lower risk of cardiovascular and all-cause mortality and increases in cardiorespiratory fitness and endothelial

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function, and reductions in blood lipids and insulin resistance [11–13]. On top of this, physical activity can be beneficial for glycemic control [14,15] and in body weight regulation [16,17]. While physical activity levels are generally low across the globe most of the data comes from areas, such as the US and Europe, where the climate is relatively cool. There is little data, for example, from warmer areas such as the Middle East where, as mentioned, diabetes is highly prevalent and limited data indicates that physical activity is low [18].

Low physical activity appears to be a particular problem in Kuwait, as a case study of a country in the Middle East region, with only ~35 % of the Kuwaiti population estimated as being sufficiently physically active, with men more physically active than women [18]. Similarly, only around a third of people with type 2 diabetes were defined as being physically active [19,20]. These reports are based on limited and self-reported data, and it is known that self-reported physical activity levels suffer from reporting bias [21]. There is no data in people with type 1 diabetes, nor any objectively measured physical activity data, which has confirmed these sex differences. The use of accelerometers to objectively measure physical activity is, therefore, desired, and also allows quantification of sleep which is also important in type 1 diabetes [22] and of novel physical activity metrics such as the intensity gradient, which quantifies the distribution of physical activity intensity [23]. Previous work has shown that overall physically activity and intensity gradient are independently associated with body composition and physical function in young girls and people with type 2 diabetes [23]. There has been no investigation of such relationships in people with type 1 diabetes. Furthermore, it is unlikely that physical activity and sleep levels are consistent across the year due to the aforementioned hot climatic conditions in the Middle East region, which is often cited as a barrier to physical activity [24].

The primary purpose of the current study was to quantify physical activity, sedentary behaviours and sleep levels in people with type 1 diabetes in Kuwait using wrist worn accelerometers across the different seasons and Ramadan. Our primary hypothesis was that physical activity levels would be lower in the summer/spring compared to the autumn/winter. Secondary aims were to determine whether any sex differences in these variables exist and to investigate associations of physical activity variables with measures of body composition and glycaemic control. We hypothesized that physical activity would be lower in women compared to men, and that overall physical activity and the intensity gradient would be independently associated with body mass index (BMI), waist circumference and glycated hemoglobin (HbA1c). Achieving these aims will deliver innovative findings that can be valuable for targeting and developing interventions aimed at improving physical activity and glycemic control in people with type 1 diabetes.

2. Material and methods

2.1. Setting and participants

From August 2021 to September 2022 people with type 1 diabetes, attending clinics at the Dasman Diabetes Institute in Kuwait, were invited to participate in the study. All participants had a documented diagnosis of type 1 diabetes (per American Diabetes Association (ADA) 2022 definition/criteria). This was confirmed by an undetectable C-peptide level at diagnosis and the presence of autoantibodies consistent with the diagnosis of type 1 diabetes. All participants were enrolled in the Dose Adjustment for Normal Eating (DAFNE) program, a structured education program for type 1 diabetes, thus practicing carbohydrate counting and appropriate insulin dosing. The study was approved by the Ethical committee of Ministry of Health, Kuwait (435/2016) and followed the guidelines set out in the Declaration of Helsinki. For the current study demographic and clinical data were collected and following this an accelerometer worn for a 7-day period. The study was fully explained to the participants, both orally and in writing, prior to them providing written informed consent.

2.2. Demographics

Age was calculated from participants' date of birth, clinical history recorded, and measurements of body mass, height, BMI and waist circumference made. The clinical data, such as HbA1c, total cholesterol, HDL cholesterol, LDL cholesterol and triglycerides were collected from the electronic health records during the same visit. For seasonal purposes the following definitions were applied: Summer = June, July, August; Autumn = September, October, November; Winter = December, January, February; Spring = March, April, May; and Ramadan (which occurred in April in 2022). We also collected the daily atmospheric temperature from the Kuwait meteorological department web site and measured the average temperature in Kuwait.

2.3. Accelerometery

Participants were issued with a GENEActiv original accelerometer and instructed to wear this 24-h per day for a 7-day period. The accelerometer was set to record at 100 Hz. This device and 7 day recording period has previously been shown to give a valid and reliable measurement of habitual physical activity levels [25,26].

2.4. Data processing

To generate overall summary data for physical activity, sedentary behaviour and sleep analysis was performed using GGIR [27]. Acceleration data collected was calibrated to local gravity using the methods established by van Hees et al. [28]. Physical activity levels were quantified using methods previously described [29,30] with the intensity distribution calculated according to previously published methods as [23]. Briefly the natural log of both intensity and time accumulated at that intensity was plotted for each participant and the gradient of the line used as the intensity gradient. Sleep was detected, without a sleep log using previously established methods with sleep efficiency defined as the time asleep within the sleep period window time [31]. A valid day was defined as having >16 h of data in it, and we excluded participants with less than 3 valid days of data or if wear data were not present for each 15-min period of the 24-h cycle. From this analysis we quantified, overall physical activity using the average acceleration across the day, the Euclidean Norm Minus One, measured in mg. We also quantified time spent sedentary (0–40 m*g*), time spent doing light (40–100 m*g*), moderate (100–400 m*g*), and vigorous physical activity (>400 m*g*), the intensity gradient and intercept, and sleep duration and efficiency. To investigate the time course of physical activity accelerometer data were processed to generate 24 h data for overall activity and in acceleration categories of: 0–40 m*g*, 40–100 m*g*, 100–200 m*g*, 300–400 m*g* and >400 m*g*. Such a broad range of physical activity parameters were selected to quantify different aspects of physical activity – overall amount, distribution of intensity and time spent at different intensities to give an accurate overall picture of physical activity.

2.5. Statistical analysis

Normality was checked using the Shapiro-wilk test. Physical activity and sleep variables were compared between the seasons using a one-way ANOVA. The average (across all seasons) physical activity and sleep variables were compared between sexes using Mann Whitney U tests. To investigate the association of average (across the seasons) physical activity and sleep variables with BMI, waist circumference and HbA1c score we used multiple linear regression analysis with the following models: unadjusted (model 1); adjusted for age, duration of diabetes and sex (model 2); and adjusted for model 2 + intensity gradient (when overall activity was exposure) or overall activity (when intensity gradient was exposure) (model 3). This analysis was performed in all participants and also stratified by sex. Significance was accepted as $p < 0.05$ and R and SPSS used for statistical analysis.

3. Results

The demographic and clinical characteristics of the participants are presented in Table 1. Accelerometer metrics were compared across the seasons, with seasonal differences seen in overall activity ($p = 0.05$), inactivity ($p = 0.04$), light activity ($p = 0.001$), the intensity gradient ($p = 0.001$) and sleep efficiency ($p = 0.02$). No seasonal differences were seen in moderate ($p = 0.60$) or vigorous ($p = 0.64$) physical activity, or sleep duration ($p = 0.22$). Seasonal physical activity and sleep data are presented in Table 2. Overall activity during the winter and autumn seasons was higher than in the spring and summer seasons ($p = 0.05$). Time spent in inactivity was higher during the spring and summer seasons ($p = 0.04$). In contrast, light activity was higher during the autumn and winter seasons ($p = 0.001$). The intensity gradient was lower during the summer season ($p = 0.001$). Overall activity was lowest in the Summer and highest in the Autumn, with a similar pattern for the intensity gradient. Inactivity was highest in Spring and lowest in Autumn, with light physical activity highest in Autumn and lowest in Summer. Sleep efficiency was lowest in Summer and broadly comparable across the other 3 seasons. Overall activity was inversely correlated with the atmospheric temperature ($r = -0.65$, $p = 0.02$), as was the intensity gradient ($r = -0.82$, $p = 0.01$) with the data visualized on a monthly basis in Fig. 1.

Comparing physical activity and sleep measured during Ramadan, which occurred in Spring, with data collected in Spring, but not Ramadan, there were no differences in overall activity ($p = 0.41$), or moderate ($p = 0.28$) or vigorous ($p = 0.21$) physical activity. However, the intensity gradient ($p < 0.001$), inactivity ($p = 0.01$) and light physical activity ($p < 0.001$) were higher and sleep duration ($p = 0.01$) and sleep efficiency ($p = 0.04$) lower.

Supplementary Fig. 1 presents the physical activity pattern in a 24-h cycle. It can be seen that physical activity levels, at all intensities, increase from around 5am, with a slight plateau around 5pm and begin to decline at around 10pm. The opposite is seen for inactivity (0–30 mg). Supplementary Table 1 presents the overall accelerometer-measured physical activity metrics among participants using multiple daily injections and continuous subcutaneous insulin infusion. Mann-Whitney U tests revealed that continuous subcutaneous insulin infusion users had a longer sleeping duration ($p = 0.03$) and higher sleep efficiency ($p < 0.001$) than multiple daily injection participants. No other variables were different between the two groups. The accelerometer measured physical activity metrics overall and by sex are presented in Table 3. Mann-Whitney U tests demonstrated that overall activity ($p = 0.02$), moderate ($p < 0.01$) and vigorous physical activity ($p < 0.01$) levels, and inactivity ($p = 0.01$) were higher in males compared to females. Females had a longer sleeping duration ($p = 0.02$), and higher sleep efficiency ($p = 0.04$) and light physical activity ($p = 0.01$).

Table 1
Baseline Demographics total and by sex.

Variables	Total (n = 784)	Male (n = 371)	Female (n = 413)
	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	34.2 (9.9)	34.4 (9.8)	34.0 (10.0)
Height (cm)	165.3 (9.5)	172.1 (7.8)	159.2 (6.1)
Weight (kg)	74.8 (15.4)	80.6 (16.8)	69.5 (11.6)
BMI (kg/m^2)	27.3 (4.7)	27.2 (5.1)	27.4 (4.3)
Duration of diabetes (years)	21.4 (7.3)	22.9 (105.5)	20.1 (8.7)
HbA1c (mmol/mol)	62.3 (14.8)	63.8 (15.8)	61.0 (13.6)
Total Cholesterol (mmol/L)	4.5 (1.0)	4.3 (1.1)	4.7 (0.8)
HDL Cholesterol (mmol/L)	1.6 (0.4)	1.4 (0.3)	1.7 (0.4)
LDL Cholesterol (mmol/L)	2.5 (0.9)	2.5 (1.0)	2.6 (0.9)
Triglycerides (mmol/L)	0.9 (0.7)	1.1 (0.8)	0.8 (0.6)
Waist Circumference (cm)	91.0 (15.0)	94.6 (14.2)	87.8 (14.9)
Daily Insulin Dose (U/day)	47.6 (19.9)	54.5 (21.4)	41.2 (16.0)
Taking Oral Antidiabetic Medication n (%)	288 (36.7)	146 (39.4)	142 (34.3)

Oral antidiabetic medications included: Empagliflozin, Dapagliflozin, Metformin, Victoza

The associations of physical activity and sleep metrics with BMI, waist circumference, and HbA1c value are presented in Table 4. Only sleep efficiency ($p = 0.01$) was positively associated with BMI in model 1 and in model 3 the intensity gradient ($p = 0.01$) was negatively associated with BMI. No other variables were associated with BMI across the models. Sleep efficiency was positively associated with waist circumference in models 1 ($p = 0.03$) and 2 ($p = 0.05$). No other variables were associated with waist circumference across the models. Overall physical activity ($p = 0.02$ and $p = 0.01$) and the intensity gradient (both $p = 0.01$) were negatively associated with HbA1c levels in both models 1 and 2, but not in model 3 after mutual adjustment. Supplementary Table 2 presents the association of accelerometer measured physical activity and sleep metrics with the outcomes of interest - BMI, waist circumference and HbA1c stratified by sex. After adjustment (models 2 and 3) there were no associations of physical activity and sleep with BMI, waist circumference or HbA1c in women. In men (model 2) overall activity was positively associated with BMI and HbA1c, the intensity gradient was negatively associated with waist circumference and HbA1c, and sleep efficiency positively associated with BMI and waist circumference. In model 3, after mutual adjustment overall activity remained associated with BMI and the intensity gradient was associated with BMI and waist circumference.

4. Discussion

The current study has demonstrated that in Kuwait, a country within the Middle East region, there are clear seasonal differences in physical activity and sleep characteristics with lower physical activity, poorer sleep and more inactivity during summer and spring relative to winter and autumn. During the period of Ramadan, inactivity and light physical activity were higher and sleep duration and efficiency lower. Sex differences in data were also seen, with overall activity higher in men, with this primarily driven by higher levels of moderate and vigorous activity. Sleep duration and efficiency were higher in women. In our final analysis we found that overall physical activity and the distribution of physical activity intensity were associated with glycaemic control, highlighting their importance for people with type 1 diabetes, with this association seen primarily in men. Overall, this information provides us with a comprehensive overview of physical activity and sleep in people with type 1 diabetes, which can highlight where and how to direct public health interventions. This data is not without limitations and further works is required to confirm and extend these findings.

This was the first study to use accelerometers to measure physical activity in people with type 1 diabetes in Kuwait. In fact, there are very few studies which have quantified physical activity and sleep in adults with type 1 diabetes. One small study from the UK demonstrated that physical activity levels in people with type 1 diabetes are lower than healthy adults of a similar age [32,33]. We cannot, however, make direct comparisons with this data due to differences in data processing methods. We can make some comparisons with data processed in a similar way in the UK Biobank [34] where overall daily physical activity was around 30 mg in those aged 45–54 years, which is around 20 % higher than seen in our data, even though people were older than in the current sample. Indeed, the overall daily acceleration in the current cohort was similar to the levels seen in people with type 2 diabetes (age 60 years) in the UK [35]. Overall, therefore, physical activity levels in people with type 1 diabetes in Kuwait are low. We have also demonstrated that these vary by season.

The seasonal pattern of physical activity levels in Kuwait differs from the western countries primarily because of the extreme hot weather conditions alongside cultural differences. In countries like the UK

Table 2
Basic physical activity characteristics by seasons.

Physical activity metrics	Summer (n = 182)	Autumn (n = 119)	Winter (n = 138)	Spring (n = 149)	p-value[a]	Spring Ramadan (n = 196)	p-value[b]
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)		Mean (SD)	
Overall activity (mg)	24.2 (7.2)	26.2 (7.6)	26.1 (7.9)	25.1 (7.0)	0.07	25.0 (7.0)	0.94
Intensity Gradient	−2.45 (0.3)	−2.08 (0.2)	−2.05 (0.2)	−2.25 (0.3)	<0.001	−2.14 (0.2)	<0.001
Waking Time Inactivity (min/day)	734.6 (120.7)	714.2 (108.3)	722.6 (122.9)	740.4 (125.1)	0.27	797.2 (154.3)	<0.001
Waking Time Light Activity (min/day)	184.1 (55.7)	226.1 (64.6)	217.0 (67.0)	196.4 (59.2)	<0.001	232.3 (81.7)	<0.001
Waking Time Moderate Activity (min/day)	72.4 (40.3)	66.0 (39.9)	71.7 (49.4)	72.0 (39.9)	0.58	64.2 (38.1)	0.07
Waking Time Vigorous Activity (min/day)	2.1 (2.9)	1.8 (3.8)	1.5 (3.9)	2.0 (4.0)	0.60	1.3 (3.8)	0.12
Sleep Duration (min/day)	345.9 (83.1)	362.0 (75.5)	360.5 (77.4)	356.2 (70.9)	0.24	327.4 (88.7)	0.001
Sleep Efficiency	83.7 (14.0)	86.6 (8.1)	86.2 (10.3)	87.0 (7.5)	0.02	85.9 (10.0)	0.03
Daily Insulin Dose (U/day)	48.3 (20.1)	49.2 (24.9)	45.3 (16.1)	49.2 (19.8)	0.39	46.5 (19.1)	0.21

[a] , ANOVA test between summer, Autumn, Winter and Spring seasons.
[b] , *t*-test between Spring and Spring Ramadan.

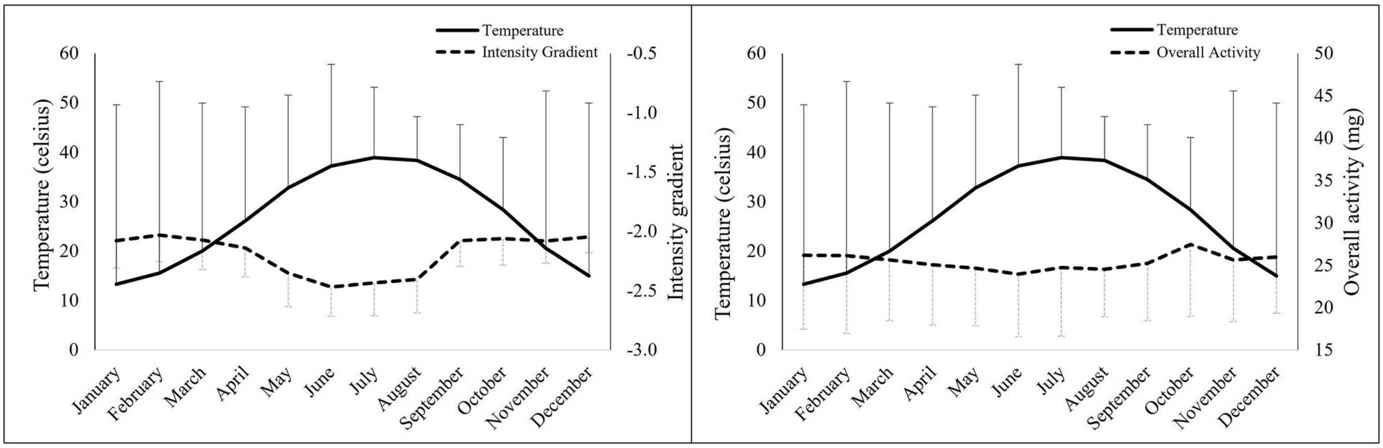

Fig. 1. Seasonal variation in overall activity and the intensity gradient in people with type 1 in relation to daily temperature overall activity and the intensity gradient data are mean (SD) and the temperature in mean daily temperature (maximum temperature).

Table 3
Basic physical activity characteristics total and by sex.

Physical activity metrics	Total (n = 784)	Male (n = 371)	Female (n = 413)	p-value[a]
	Mean (SD)	Mean (SD)	Mean (SD)	
Overall activity (mg)	25.2 (7.3)	25.8 (7.6)	24.6 (7.1)	0.02
Intensity Gradient	−2.2 (0.3)	−2.2 (0.3)	−2.2 (0.3)	0.00
Waking Time Inactivity (min/day)	746.2 (132.7)	758.3 (135.5)	735.2 (129.3)	0.01
Waking Time Light Activity (min/day)	210.7 (69.4)	203.4 (69.5)	217.2 (68.8)	0.01
Waking Time Moderate Activity (min/day)	69.2 (41.5)	74.3 (39.9)	64.6 (42.3)	<0.001
Waking Time Vigorous Activity (min/day)	1.7 (3.7)	2.5 (4.6)	1.0 (2.3)	<0.001
Sleep Duration (min/day)	348.3 (81.2)	341.0 (84.6)	354.7 (77.5)	0.02
Sleep Efficiency	85.5 (10.5)	84.7 (11.2)	86.3 (9.8)	0.04

[a] p value by the Mann-Whitney *U* test.

physical activity levels are generally highest, and inactivity lowest, in Summer and Spring [34,36,37] which is the opposite of what we find in Kuwait. In the Gulf region, the temperature rises in Spring and reaches its highest during the Summer (~ 46 °C), which can restrict outdoor activities. We also found that sleep was poorer during the Summer and Spring seasons. Seasonal differences have been demonstrated previously in Western countries with similar patterns as in Kuwait, with sleep duration lowest in Spring/Summer [38]. Seasonal factors can likely impact sleep quality through a combination of factors, including changes in light exposure, day lengths, outdoor temperature, melatonin production, and social and cultural factors which interact with circadian rhythms to alter sleep quality [38]. The current study was also able to report the first data comparing accelerometer measured physical activity and sleep during Ramadan. We found that overall activity, sleep duration and sleep efficiency were lower but inactivity and light activity were higher. These differences are perhaps not surprising as during fasting higher intensity activity is not recommended [39]. The changes in sleep will likely reflect late-night religious practices during Ramadan, for example, *Suhoor,* an early morning meal, interrupting sleep. It is worth noting at this point that during Ramadan many people will take daytime naps, which would not be captured in the sleep time metric of the current study. So overall sleep time may not actually be lower.

Our analysis of the association of physical activity and sleep metrics highlights the relative importance of these for body composition and glycemic control. It is perhaps not surprising that physical activity variables were not associated with BMI or waist circumference due to the relatively minor, yet important, role it has in weight control [40]. Sleep efficiency was associated with waist circumference which is in agreement with previous work [42]. Both overall physical activity and the distribution of physical activity intensity (intensity gradient) were associated with HbA1c, although not after mutual adjustment, which indicates that both together are important for glycemic control. No previous work has investigated the associations of the novel intensity gradient metric with glycemic control with HbA1c and so the current study provides novel information on the importance of the distribution

Table 4
Association of accelerometer measured physical activity and sleep metrics with the outcomes of interest - BMI, waist circumference and HbA1c in people with type 1 diabetes.

	Model 1			Model 2			Model 3		
	Coefficients	95 % CI	p- value	Coefficients	95 % CI	p- value	Coefficients	95 % CI	p-value
BMI									
Overall activity (mg)	0.04	−0.01, 0.08	0.09	0.04	0.00, 0.09	0.08	0.04	−0.03, 0.11	0.25
Intensity gradient	−0.58	−1.73, 0.58	0.33	−0.85	−2.04, 0.33	0.16	−1.85	−3.22, −0.49	0.01
Waking Time Inactivity	0.00	0.00, 0.00	0.22	0.00	0.00, 0.00	0.08			
Sleep duration	0.00	−0.01, 0.00	0.51	0.00	0.00, 0.00	0.91			
Sleep efficiency	0.04	0.01, 0.07	0.01	0.03	0.00, 0.06	0.09			
Waist circumference									
Overall activity (mg)	−0.01	−0.15, 0.14	0.90	−0.05	−0.19, 0.09	0.51	−0.13	−0.34, 0.07	0.20
Intensity gradient	0.47	−3.22, 4.16	0.80	−2.23	−5.80, 1.35	0.22	−2.40	−6.54, 1.75	0.26
Waking Time Inactivity	0.00	0.00, 0.01	0.23	0.00	−0.01, 0.01	0.54			
Sleep duration	0.00	−0.02, 0.01	0.52	0.00	−0.01, 0.02	0.63			
Sleep efficiency	0.11	0.01, 0.21	0.03	0.09	0.00, 0.19	0.05			
HbA1c									
Overall activity (mg)	−0.17	−0.32, −0.03	0.02	−0.19	−0.33, −0.05	0.01	−0.19	−0.39, 0.01	0.06
Intensity gradient	−5.12	−8.75, −1.48	0.01	−4.69	−8.28, −1.11	0.01	−2.78	−6.95, 1.39	0.19
Waking Time Inactivity	0.00	0.00, 0.01	0.26	0.01	0.00, 0.01	0.09			
Sleep duration	0.00	−0.02, 0.01	0.67	0.00	−0.02, 0.01	0.44			
Sleep efficiency	0.04	−0.06, 0.13	0.48	0.03	−0.06, 0.13	0.52			

Model 1 is unadjusted. Model 2 is adjusted for age, duration of diabetes and sex. Model 3 is adjusted for model 2 + intensity gradient when Overall activity was the exposure, and when intensity gradient was the exposure model 3 was adjusted to model 2 + Overall activity.

of physical activity intensity. Perhaps surprisingly, when analysis was performed stratified by sex these associations were still seen in men but not in women, with little work previously investigating sex differences in this area [41]. Previous research investigating the association of overall physical activity with HbA1c in people with type 1 diabetes has been mixed [43], although the current data support a role for it in glycemic control. However, this analysis cannot confirm causality in our observations. There is, however, data to demonstrate a causal relationship between physical activity and HbA1c. Several studies have shown that in the general population and in people with type 1 diabetes physical activity causes an insulin independent increase in skeletal muscle glucose uptake [44,45]. For example, the contraction of muscles activates the Ca2+/calmodulin-activated protein kinase family, 5′-AMP-activated protein kinase, and atypical protein kinase C (PKC), which regulate the translocation of glucose transporter protein 4 and the uptake of glucose in skeletal muscles [44,45]. There is also evidence that this relationship is influenced by the intensity of physical activity, with a higher intensity of activity resulting in greater glucose uptake [44].

The current data has clear clinical relevance in the Middle East and beyond with regards physical activity. Our data highlights the magnitude of physical inactivity in people with type 1 diabetes in Kuwait, a population never studied before, which likely translates across the Middle East region and other countries with such hot climates. This reinforces the need for health professionals to promote physical activity in this population, which may result in a multitude of clinical benefits including for glycemic control. Our data also stimulates an interest in clinical trials to develop optimal strategies to promote physical activity in this population.

5. Limitations

This single-center study is not without limitations, and it is prudent to consider these. Not all participants were assessed every season, due to logistical reasons, which is a limitation of the study. The current study is a pragmatic cross-sectional study, not a randomised controlled trial, and so there was no control of participants carbohydrate intake or insulin dosing which may influence the associations we presented. On top of this we did not measure dietary intake or have data on socioeconomic status, which may influence our study outcomes and is something that should be assessed in future work. Lack of age and BMI matched control is a major limitation of this study as it would be informative to have an age and BMI matched control group of participants from Kuwait to allow us to establish how different people with type 1 diabetes are to the general Kuwaiti population and this is something the future work should consider, although we were able to compare to other similar populations for other countries. As mentioned, all our participants took part in the DAFNE program and followed its educational guidance throughout. The participants were recruited from clinics at the Dasman Diabetes Institute in Kuwait, which might introduce selection bias. Individuals attending these clinics might have different characteristics compared to those who do not seek healthcare services or attend different clinics, potentially affecting the generalizability of the findings. As we detailed these findings need to now be explored in an appropriate RCT accounting for such potentially confounding variables. The key strength of our study is that we objectively measured physical activity and sleep, in a large sample of people with type 1 diabetes – an understudied group. On top of this we were able to, for the first time, make multiple measurements to quantify seasonal differences in physical activity and sleep, which is particularly important in Kuwait where the summer weather is extreme.

6. Conclusion

Overall, accelerometers provide an objective measure of physical activity and sleep and the current data has quantified these metrics in people with type 1 diabetes in Kuwait, highlighting the overall poor physical activity/sleep and the variation in these metrics across the seasons and between sexes. Overall daily physical activity and the distribution of physical activity intensity are important for glycemic control. This data can help to direct and target interventions to improve physical activity and sleep in people with type 1 diabetes.

Conflicts of interest statement

The authors have no conflicts of interest to declare.

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Author contributions

Conceptualization, EAO, SRG and AAO; data acquisition, MI, AV, JAK, ET, AM, AA and SM; analysis and writing- original draft, SRG and

MI; critical review and editing, EAO and SRG. All authors have read and agreed to publish this manuscript.

Ethical approval and consent to participate

The study was approved by the Ethical committee of Ministry of Health, Kuwait (435/2016) and followed the guidelines set out in the Declaration of Helsinki. All participants signed the consents and agreed to follow.

Data availability statement

Data will be available from reasonable request from the corresponding author.

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Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dsx.2024.103046.

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