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Original/*Pediatría*

Objectively measured physical activity and sedentary behaviour patterns in Chilean pre-school children

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Abstract

Introduction: **the negative effects of physical inactivity and sedentary behaviour (SB) on children's health have been widely supported by evidence. However, evidence on how these behaviours are manifested in pre-school children is limited. The study aim was to evaluate objectively measured physical activity (PA) and SB patterns in Chilean pre-school children.**

Methods: **twenty-five children (4.8 ± 0.50 years, 48% male) completed ambulatory monitoring with an ActivPAL™ micro accelerometer and inclinometer. Time spent while walking, standing and sitting/lying, as well as daily steps were measured and compared by day of the week (weekday/weekend) and time of day.**

Results: **mean walking time was 147.2 ± 52.23 minutes/day. Mean time spent in SB was 468.3 ± 92.22 min/day, with statistical differences between week and weekend days (484.8 minutes/day *vs.* 426.8 minutes/day, p = 0.03). 50% of total steps were accrued in accumulations of less than 100 steps/minute, while 50% of time spent in SB was accumulated in bouts of 35 seconds or less.**

Discussion: **pre-school children have intermittent PA and SB patterns. On weekdays children spent sitting longer than at weekends, therefore an opportunity exists for changing this behaviour during class time. This report on PA and SB patterns presents valuable information for designing and implementing strategies to enhance PA levels and decrease time spent in SB among pre-school children.**

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Key words: *Accelerometry. Walking. Ambulatory measurement. Physical activity. Sitting.*

PATRONES DE ACTIVIDAD FÍSICA Y CONDUCTA SEDENTARIA MEDIDOS OBJETIVAMENTE EN PREESCOLARES CHILENOS

Resumen

Introducción: **los perjuicios de la inactividad física y de la conducta sedentaria (CS) en la salud de los niños han sido ampliamente respaldados por la evidencia. Sin embargo, existe limitada evidencia de cómo estos comportamientos se manifiestan en los preescolares. Por este motivo, este estudio tuvo como propósito evaluar los patrones de actividad física (AF) y CS de forma objetiva en preescolares chilenos.**

Método: **25 niños (4,8 ± 0,50 años, 48% hombres) completaron la monitorización ambulatoria con el acelerómetro e inclinómetro ActivPAL™ micro. Se midieron tiempos caminando, de pie y sentado/acostado, además de pasos acumulados por día, para ser comparados según día de la semana y período del día.**

Resultados: **el tiempo promedio caminando fue de 147,2 ± 52,23 minutos/día. El tiempo en CS fue de 468,3 ± 92,22 minutos/día, con diferencias estadísticas entre días entre semana y fin de semana (484,8 *vs.* 426,8 min/día, p = 0,03). El 50% de los pasos fueron sumados en acumulaciones menores a 100 pasos/minuto, mientras un 50% del tiempo en CS fue acumulado en intervalos de duración de 35 segundos o menos.**

Discusión: **los preescolares presentan patrones intermitentes de AF y CS. En los días entre semana se sientan más que durante el fin de semana, por lo cual se presenta una posibilidad de modificar este comportamiento durante el período de clases. Este reporte de patrones de AF y CS en preescolares presenta información valiosa para el diseño e implementación de estrategias para mejorar los niveles de AF y disminuir el tiempo en CS en preescolares.**

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Palabras clave: *Acelerometría. Caminar. Medición ambulatoria. Actividad física. Sentarse.*

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Introduction

The evidence suggests that the amount of time spent in sedentary activities is related with obesity and other physical and psychological health problems in children[1]. The current recommendation on the amount of physical activity (PA) that pre-school children should perform indicates that they should accumulate at least 60 minutes per day of structured PA and should not remain in sedentary behaviour (SB, defined as activity while seated or lying with energy expenditure ≤ 1.5 METs during waking hours)[2] for more than 60 consecutive minutes[3]. It has been shown that children who do not accumulate at least 60 minutes of moderate to vigorous PA per day present a greater predisposition to suffer over-weight or obesity compared to their peers who comply with the recommendations[4]. If current trends continue, it is projected that by 2025 the number of young children suffering overweight will increase to 70 million[5].

In 2014, Hnatiuk *et al*. published a review of the evidence related with objectively measured PA levels and time spent in SB in pre-school children, which showed a wide variation in estimated prevalence[6]. The reported ranges varied from 2% to 41% for time spent in moderate to vigorous PA, and 34% to 94% for the proportion of time spent in SB by pre-school children[6]. Due to this wide variation in the reported data, and the lack of studies in this area from developing countries, it is important to evaluate pre-school children in different regions both to determine PA patterns and to obtain evidence as to whether or not this population complies with the minimum PA recommended for individuals in their age-group. Apart from its association with children's health, it has been observed that higher PA levels in the initial stages of life influence the acquisition of motor skills, and PA types influence locomotor patterns[7-9]. All this becomes even more important if we consider all the negative associations between SB and a variety of health problems[1,10].

One of the most widely recognised instruments for measuring objectively both PA levels and SB is accelerometry[11,12]. Research has been done in diverse countries around the world in which different accelerometers have been used to evaluate these parameters in pre-school populations[13,14]. One of these devices is ActivPAL™ (AP), which was selected as the evaluation method for the present study because it has proved to be the best at measuring and identifying times spent in postures such as sitting/lying, standing and walking, a very useful characteristic for determining time spent in SB[11,15]. It also allows time spent walking and total number of steps taken in a given period to be determined[11]. The evidence shows that AP offers acceptable validity, utility and reliability in measuring posture and activity during the daily activities of pre-school children[16]. Furthermore, experts in SB evaluation suggest that when analysing the data, not only should total time in SB (which is usually reported) be included but also other types of analysis, for example how PA and SB were distributed in terms of step accumulation per minute or bouts of SB[11].

Our objective was to evaluate PA and SB patterns in pre-school children, using the AP accelerometer. Apart from analysing total times in SB, standing and walking, these times were also analysed as percentages of the total wearing time and differences were noted by gender, nutritional status, time of day and weekday vs. weekend. The accumulated steps per minute and walking bout duration were included to identify how daily minutes of PA were accrued.

Method

This study of PA and SB patterns in pre-school children included a randomly selected sample from a public school in Temuco, southern Chile. The study included children aged 4 to 5 years who were able to walk independently without the use of assistive devices. Parents or tutors signed an informed consent and children gave their assent.

Demographic data such as age and gender were recorded, and anthropometric details such as weight (weight scale, model Seca 8803, Hamburg, Germany) and height (stadiometer, Prestige, India) to determine the body mass index according to World Health Organisation standards (zBMI, $m \bullet kg^{-2}$)[17].

Each child was asked to wear a PA monitor, ActivPAL™ micro (AP, PAL Technologies Ltd, Glasgow, UK) continuously, 24 hours per day, for at least 4 days (including two weekend days)[16]. The AP monitor was fitted directly to the skin on the medial-anterior part of the right thigh. The device was sealed with a nitrile finger cot and attached to the skin with a transparent and hypoallergenic tape (Tegaderm™, 3M™, MN, USA) to provide a waterproof barrier. During wearing days, children were asked to continue with their normal activities, which included attending educational activities in the afternoons during weekdays.

The ActivPAL™ micro monitor is a small (23.5mm x 43mm x 5mm), light (10gr) triaxial accelerometer, with data storage capacity for at least 10 consecutive days. It can distinguish very accurately time spent sitting/lying, standing or walking[16], and transitions between these postures (standing up and sitting down). However, its capacity for distinguishing between sitting and lying positions is limited[18]. AP can also quantify steps and accumulation in periods of time.

Data processing

ActivPAL™ Professional software v7.2.32 Research Edition (PAL Technologies Ltd, Glasgow, UK) was used to download the data. A manual filter was applied to detect the hours when the participants were awake, as done in previous studies with the AP event files[19].

The waking-up time of each participant was defined by the first *standing-up* transition of the morning, and the time the participant went to sleep by the last *sitting-down* transition of the evening. Once the manual filter of waking hours was applied, the participants' data were entered and processed in Stata software, version 12 (StataCorp. College Station, TX, USA). For all children, the minimum wearing time required for a day to be valid was at least 6 waking hours[16].

Total times spent sitting, standing and walking were calculated in minutes per day, and as a percentage of the total wearing time. The latter was to establish a better comparison since the participants presented different wearing times and waking hours. Times spent in each activity were also determined for different times of day. These times were defined as "before class" (from waking-up until 1:59 pm), "in class" (2:00 pm to 5:59 pm) and "after class" (6:00 pm until going to sleep). Weekdays were compared with weekend days for total times per day and per time of day. To evaluate how SB behaviour was accumulated in bouts, we estimated the average duration of these bouts to be compared between weekdays and weekends. Similarly, to evaluate how PA was accumulated, walking bouts were created to estimate "Time in PA in bouts of at least 5- or 10-minute duration". For walking to be considered as a bout, it had to be maintained for at least 5 or 10 minutes consecutively[10,20], but allowing for interruptions or hesitations of less than 60 seconds for possible resting or waiting during the activity. Estimates of PA and SB for an average day were calculated in the same way used in previous studies (e.g. average steps per day = (5 • steps per weekday + 2 • steps per weekend day)/7)[21,22].

Average total steps per day were estimated for weekdays and weekend days. AP records the number of steps taken in a given minute or period of time. This variable is reported as step accumulation per minute. It should be noted that in the present study the term step accumulation is used instead of step cadence, since the terms are not interchangeable[23,24]. The step accumulation per minute was used as a proxy for the energy expenditure required for the activity[25]. Total walking minutes were distributed according to step accumulation measured in an average weekday and an average weekend day. Frequency distributions were plotted to show how these accumulations per minute contribute to the daily percentage of total steps in an average weekday and weekend day. Furthermore, in order to evaluate walking and SB patterns in terms of bout duration, these intervals were distributed according to the percentage that they contributed to the daily total. Not only the average duration of SB bouts were reported, but also duration of the intervals which accumulate 50% (percentile 50) and 90% (percentile 90) of the total time spent in SB[19]. The variables were reviewed for normal distribution; means and standard deviation were used to represent the normally distributed values, and percentages for the category variables. Student's T tests (normal distribution) and Chi^2 test (categoric variables) with significance $p = 0.05$ were used for all the comparisons.

Results

Of a total of 26 pre-school children, 25 completed their participation in the study (4.8 ± 0.50 years, 48% men). In the total sample, 32% had normal weight, 28% were overweight and 40% obese. Men presented a higher percentage of obesity than women (58% vs 23%).

The average time spent in sedentary behaviour (SB) was 468.3 ± 92.22 minutes/day (Table I) and participants tended to sit more during weekdays than weekends ($p = 0.03$). The percentage of time spent in SB per day also presented statistically significant differences between these days (59.0% vs. 50.8%, $p = 0.03$). However, no differences were found between average SB bout duration between weekdays and weekends ($p = 0.94$). Further, no differences were observed between weekdays and weekends for time spent standing, time spent walking and total number of steps per day. The total time per day in continuous PA, for both 5 and 10 minutes, showed statistically significant differences between weekdays and weekends ($p < 0.001$), but no differences were observed for gender or nutritional status.

When total percentages of time per day spent sitting, standing or walking were analysed, statistically significant differences were only observed for percentage of time spent sitting between weekday and weekend in class ($p = 0.002$) and after class ($p = 0.04$) (Table II).

It was observed that from the total steps at least 50% were accrued in accumulations of less than 100 steps per minute and 28.7% in accumulations above 120 steps per minute in an average day (Fig. 1). Comparisons were made between distributions on weekdays and weekend days, but no statistically significant differences were found for any of the accumulations.

For the percentage distribution of walking bout duration, 57.7% of total walking time in an average day was completed in bouts that lasted less than 10 seconds (Fig. 2A). It is also of interest to note that only 4% of this total walking time was completed in bouts that lasted 60 seconds or more. No differences were observed in these distributions between week and weekend days.

SB bouts (Fig. 2B) of 15 seconds to less than 1 minute presented the highest percentages (28%) in an average day, followed by SB bouts of 90 to 179 seconds (12.0%). Only 11.3% of the time spent in SB was accumulated in bout equal to or greater than 5 minutes. No differences were observed in these distributions of SB between weekdays and weekends.

Discussion

This is the first study conducted in Chile to objectively measure SB and PA patterns in pre-schoolers with the ActivPAL™ accelerometer. The principal findings

Table I
Total times in sedentary behaviour, standing and walking during an average day, weekdays and weekends, among participants

	Average day	*Weekday*	*Weekend day*	*p*
Total time in SB (min/day)				
Mean	468.3	484.8	426.8	0.03
SD	92.22	105.86	103.7	
Percentage of day in SB (%)				
Mean	55.9	58.0	50.8	0.03
SD	8.84	11.06	10.13	
SB bout duration (min)				
Mean	9.3	9.3	9.1	0.94
SD	8.60	8.48	10.57	
p50	0.58	0.65	0.51	
p90	5.65	5.94	5.06	
Total standing time (min/day)				
Mean	219.7	212.5	237.8	0.23
SD	35.51	50.25	63.04	
Percentage of day standing (%)				
Mean	26.7	26.0	28.5	0.35
SD	6.16	8.41	7.38	
Total walking time (min/day)				
Mean	147.2	141.9	160.4	0.18
SD	52.23	55.35	66.47	
Percentage of day walking (%)				
Mean	17.7	17.2	19.0	0.30
SD	6.26	7.06	7.41	
Total steps (steps/day)				
Mean	10780.2	10324	11920.5	0.15
SD	3563.97	3749.73	5033.02	
Total time in PA in bouts of at least 5 minute duration (min/day)*				< 0.001
Mean	132.5	93.5	199.2	
SD	67.94	64.46	109.64	
Total time in PA in bouts of at least 10 minute duration (min/day)*				< 0.001
Mean	97.1	63.7	149.0	
SD	53.0	54.92	83.64	

SB: sedentary behaviour; SD: standard deviation, PA: physical activity.
*Allowing for interruptions or hesitations of less than 60 seconds for possible resting or waiting during the activity.

of this study were that children tend to remain seated for approximately 1 more hour during weekdays than weekend days, and that they accumulate more minutes of continuous PA during the weekends. No differences were observed in PA and SB patterns between gender or nutritional status, which agrees with results reported in pre-schoolers from Sweden[26].

When PA patterns in this sample were assessed, no statistically significant differences were observed for total walking time per day between weekdays and weekends, similar to results reported previously in another study of obese pre-schoolers published ten years ago in Chile[27]. Furthermore, no differences were observed between weekdays and weekends in the average SB bout duration. However, differences were observed for the total time in continuous PA per day between weekdays and weekends when accumulated in both 5- and 10-minute bouts. As with SB, one of our objectives was to identify how these minutes in PA were accumulated, since it is necessary to consider not only the total PA time accumulated in short periods, but also whether it was accumulated in longer bouts (e.g. 5 and 10 minutes). This aspect is important since it is recommended that PA may be accumulated predominantly in this way to obtain greater health benefits such as lower BMI and waist circumference[10,20]. However, where it is impossible to implement activities for promoting longer periods of continuous PA, activities may be implemented in shorter periods more frequently during the day[28,29]. In this context, a study of children aged 7-8

Table II
Percentage of day in sedentary behaviour, standing and walking during different times of day

		Average day (mean, SD)	*Weekday (mean, SD)*	*Weekend day (mean, SD)*	*p*
Percentage of day in SB (%)	Before class	21.7 (4.56)	21.2 (5.94)	22.7 (6.04)	0.45
	During class	13.9 (2.84)	15.3 (3.97)	10.5 (3.88)	0.002
	After class	20.7 (5.16)	21.5 (5.82)	18.6 (5.72)	0.04
Percentage of day standing (%)	Before class	8.1 (3.29)	7.9 (3.82)	8.6 (3.32)	0.39
	During class	8.5 (2.48)	7.8 (2.85)	10.1 (4.40)	0.05
	After class	10.1 (2.41)	10.1 (3.78)	10.3 (4.90)	0.92
Percentage of day walking (%)	Before class	4.6 (1.91)	4.6 (2.67)	4.6 (2.24)	0.967
	During class	6.3 (2.00)	5.9 (2.10)	7.1 (3.13)	0.11
	After class	7.0 (3.62)	6.8 (4.23)	7.7 (3.62)	0.35

SB: sedentary behaviour; SD: standard deviation.

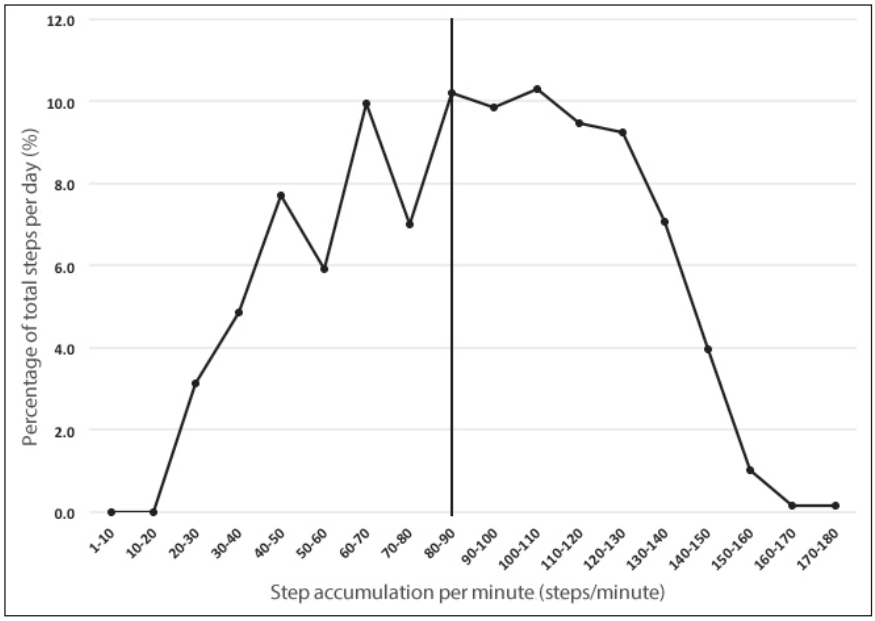

Fig. 1.—Percentage of total steps per day across step accumulations per minute in an average day. Vertical line corresponds to 50% of total steps in an average day.

years in USA reported that boys tend to accumulate a larger number of bouts of at least 5 minutes of PA than girls[20], but in our study no such difference was observed[10,20,28,29].

In this sample of pre-school children a difference was observed in the total time per day in SB between week and weekend days. This difference may be partially explained by the greater time in this behaviour observed when children were in class or after class (Table II). The percentage distribution of times in different activities during a day suggests that part of the time when the children were seated in class during weekdays was replaced by PA time at weekends. This is particularly relevant when strategies are designed to improve levels of PA in boys and girls, especially in class time during weekdays[29,30].

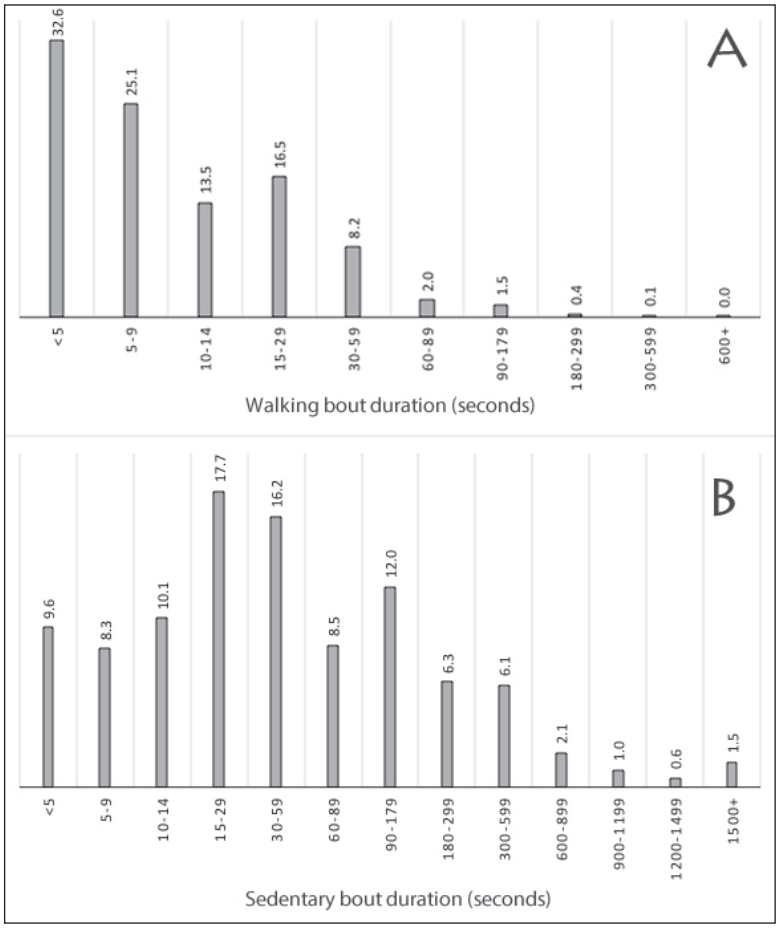

Fig. 2.—Percentage distribution of walking bout duration (A) and sedentary bout duration (B) in an average day.

Unlike common pedometers, AP allows the total number of steps taken in a day not only to be counted, but also evaluated in terms of frequency and accumulations per minute during continuous days. Consequently relations can be established to associate these parameters with energy expenditure. For example, two days may have the same number of accumulated steps, but on one of them higher-intensity activities may be performed. Step accumulation was taken as a proxy of the energy expenditure associated with their activities, since larger accumulations of steps per minute imply greater energy expenditure[25]. In this study, 50% of the total steps per day were taken in accumulations of less than 100 steps per minute. The current participants showed no differences in how the total steps per day were accrued based on the step accumulation per minute during weekdays and weekends.

In our study we observed that pre-school children tend to accumulate a large percentage of their total steps in short bouts, since around 60% of these steps were accumulated in intervals of less than 10 seconds (Fig. 2). These data showed the higher intermittence in movements observed in this age-group when compared to older children, as has been reported in other studies[26,28,30]. In contrast, only 4% of the total steps accumulated in an average day were taken in bouts lasting more than one minute. The latter aspect may become important when suggesting options for increasing PA levels in pre-school children, since it might be recommended that steps should be accumulated in longer bouts at least during physical education classes. An intermittent pattern of SB accumulation was also observed, since 50% of SB time was accumulated in bouts of 35 seconds or less, and 90% in bouts of 5.65 minutes or less. These accumulations differ slightly from values reported in Scottish pre-school children, where 50% of the time was accumulated in bouts of 50 seconds or less, and 90% in bouts of 3 minutes or less[19]. This system of results presentation has been recommended previously to favour comparability between different populations[19].

Among the strengths of the study we may mention that the participants were monitored during at least 4 consecutive days to evaluate PA and SB patterns during weekdays and weekends. The children wore the monitor uninterruptedly, allowing us to analyse whole days, not just periods in class. Of the 26 volunteer participants, only one did not complete the protocol due to a minor allergic reaction to the tape used to fix the accelerometer to the leg. This study could be improved by monitoring pre-school children during different times of year to evaluate seasonal fluctuations, and by incorporating different regions and communities with

different socio-economic levels. The study sample is relatively small, however one objective of this exploratory study was to establish foundations for implementing ambulatory monitoring with devices like ActivPAL™ on a larger scale in developing countries.

In conclusion, this study showed that pre-school children tend to be seated for longer during weekdays and perform more uninterrupted PA on weekend days. However, there is no difference in the average duration of SB bouts between these days. Most SB time during weekdays is replaced by walking time at the weekend. These findings present valuable information for the design and implementation of strategies to improve PA levels and reduce SB time in pre-school children.

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