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A cluster analysis of patterns of objectively measured physical activity in Hong Kong

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Abstract

Objective: The health benefits of exercise are clear. In targeting interventions it would be valuable to know whether characteristic patterns of physical activity (PA) are associated with particular population subgroups. The present study used cluster analysis to identify characteristic hourly PA patterns measured by accelerometer.
Design: Cross-sectional design.
Setting: Objectively measured PA in Hong Kong adults.
Subjects: Four-day accelerometer data were collected during 2009 to 2011 for 1714 participants in Hong Kong (mean age 44·2 years, 45·9 % male).
Results: Two clusters were identified, one more active than the other. The 'active cluster' (*n* 480) was characterized by a routine PA pattern on weekdays and a more active and varied pattern on weekends; the other, the 'less active cluster' (*n* 1234), by a consistently low PA pattern on both weekdays and weekends with little variation from day to day. Demographic, lifestyle, PA level and health characteristics of the two clusters were compared. They differed in age, sex, smoking, income and level of PA required at work. The odds of having any chronic health conditions was lower for the active group (adjusted OR = 0·62, 95 % CI 0·46, 0·84) but the two groups did not differ in terms of specific chronic health conditions or obesity.
Conclusions: Implications are drawn for targeting exercise promotion programmes at the population level.

Keywords
Body composition
Chronic disease
Exercise
Motor activity
Sedentary lifestyle

The health benefits of regular physical activity (PA) are well established[1], including positive associations with psychological well-being[2,3] and an inverse relationship with various illnesses[4,5]. However, general efforts to promote exercise have met limited success; potentially more specifically targeted interventions may prove more effective. To plan these, we need information on population patterns of PA to examine whether there are identifiable groups for whom interventions should be tailored and also to better estimate the impact of such interventions. Several such studies have been conducted, including cohort studies of PA levels, patterns in children and adolescents[6–9] and population-level comparisons between countries[10].

Examination of PA patterns requires a reliable and valid measure of PA. While many studies have relied on self-report questionnaires[11,12], their validity is questionable[13,14]. On the other hand, accelerometers offer an objective and reliable measurement[15] and are therefore increasingly popular in research. These electronic devices are worn by the subject to record accelerations in movement to indicate the duration and intensity of PA. Most accelerometers count accelerations larger than a specified threshold, sometimes termed an 'activity count'[16]. Most studies report average daily counts and/or total time spent on PA[10,16,17], but this does not reveal the temporal pattern of PA, such as whether the activity is concentrated in certain periods of the day. Some researchers noted this as a limitation and they have recorded bouts of PA[10,17]. However this method is also has its limitation in not distinguishing the time patterns of PA. Only by looking at PA patterns can we compare the relative effect of the duration and intensity of PA; for example, comparing the benefits of brief but intensive PA with less-intensive activities of longer duration, or whether PA occurring in the morning and at night has similar effects on health. Furthermore, with a better understanding of PA patterns, one can tailor health programmes more precisely to the needs of people who exhibit specific characteristic PA patterns.

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We present a population study of hourly PA patterns on weekdays and weekends in urban Hong Kong. To compress the large amount of data produced from the accelerometer readings, we applied a cluster analysis to group people with similar PA patterns[18]. This reveals distinct PA patterns and the clusters can be compared in terms of the people's characteristics in each cluster, including their health status. Cluster analysis has previously been used to provide daily summaries of PA, but only with questionnaire data[19,20]; ours appears to be the first study to have applied cluster analysis to accelerometer data. Whereas previous studies have provided daily summaries of PA patterns using accelerometer data[9,21], we extend this by analysing hourly PA patterns.

Methods

Participants

The present study was part of the Hong Kong Jockey Club FAMILY Project Cohort Study, funded as an initiative to promote family health, happiness and harmony in Hong Kong. It includes families recruited during March 2009 to January 2011. Sampling was based on a random selection of residential addresses provided by the Hong Kong Census and Statistics Department. A family was eligible when all members aged 15 years or older, who lived in the same address and could understand Cantonese, agreed to participate. All eligible members were interviewed by trained interviewers who entered the data into tablet personal computers. Details of the interview have been described elsewhere[22]. Having completed the main survey (n 45 767), randomly chosen participants (n 32 530) were invited to take part in a sub-study by wearing an accelerometer for four consecutive days (including a weekend). Written consent was obtained from participants (parental consent was also obtained for participants under 18 years old) and the study was approved by the Institutional Review Board of the University of Hong Kong.

Measurements

Accelerometer

Previous studies have found the ActiGraph to be reliable and valid[15,23–25]. A recent study[26] showed that 1 d of accelerometer data is adequate for estimating weekly moderate-to-vigorous PA (MVPA) in a representative US sample aged 20–85 years but we adopted a more stringent criterion because we aimed to examine hourly PA patterns. A total of 5898 participants agreed to participate and were instructed to wear an ActiGraph GT1 M uniaxial accelerometer (http://www.theactigraph.com). The ActiGraph was to be worn around the hip (right hip for right-handed and left hip for left-handed persons) for four consecutive days for all waking hours, removed only when bathing or sleeping. Instead of the conventional 7 d requirement, a 4 d measurement period was chosen to reduce user burden and encourage participation; two weekdays and two weekend days were selected on the assumption that there should be relatively little variation across weekdays. The choice of the start day (Thursday, Friday or Saturday) was up to the participant.

'Non-wear' time was defined by an interval of zero accelerometer counts for sixty consecutive minutes or more. 'Wearing' time in a day was computed by subtracting non-wear time from 24 h. A valid day had to include at least 12 h of wearing time. Only observations with four valid days of data were accepted for analysis[26]. While previous studies used a threshold of at least 10 h of registered time/d to report daily PA[9,27], we again adopted a more stringent criterion of 12 h/d.

Counts were recorded using a 1 min epoch. PA level was assessed with counts per minute, i.e. total counts divided by (60 × number of wearing hours)[10,16], and separated into time spent on MVPA and light PA (LPA)[28]. A 1 min period was classified as MVPA (≥3·00 metabolic equivalent tasks, MET) if the total counts within this period were greater than or equal to 1952[29], and was classified as LPA if the total counts ranged between 101 and 1951 (inclusive). The time spent on MVPA and LPA was the total number of moderate-to-vigorous minutes and light minutes in a day. The ActiGraph firmware version 7·5·0 was used for data transformation.

The k-means cluster analysis[18,30] was used to identify the number of distinct hourly PA patterns. Average counts per minute from 00.00 hours to 23.59 hours on both weekdays and weekends were used as cluster variables. This gave a total of forty-eight cluster variables (twenty-four for weekdays, twenty-four for weekends), allowing us to identify different PA patterns for weekdays and weekends. All cluster variables were standardized to a mean of 0 and a variance of 1 to equalize the importance of each variable. First, k (a pre-specified integer) cluster centres were randomly generated. Next, the Euclidean distance was computed between participant i and cluster centre j, which equals

$$\sqrt{\sum_{t=1}^{24}(d_{t,i}-d_{t,j})^2+(e_{t,i}-e_{t,j})^2},$$

where d and e are the standardized average counts per minute in hour t on weekdays and weekends, respectively, for all centres $j=1$ to k. Participant i was assigned to his or her nearest cluster (i.e. one with the shortest distance). After assigning all participants to their nearest cluster, the new cluster centres were recomputed using their mean, after which these steps were iterated until convergence was reached. The elbow method was used to determine the number of clusters and the pseudo R-square and Mann–Whitney U tests were used to assess the goodness-of-fit of the final cluster solution. To select an appropriate k, within-cluster sum of squares distances were computed for $k = 2$ to 10, and k was determined using the elbow method (i.e. a sudden drop of within-cluster sum of squares distances from $k-1$ to k indicates k as the appropriate solution)[31]. A dendrogram was then used to confirm the number of clusters obtained using the elbow method. Non-parametric (Kruskal–Wallis) tests were used because the forty-eight cluster variables were not normally distributed ($P < 0{\cdot}001$ for Kolmogorov–Smirnov normality tests).

Chronic health conditions

Participants were asked whether a medical practitioner had told them that they had any of eight chronic health conditions chosen to represent relatively definitive diagnoses: cancer, diabetes mellitus, hypertension, high cholesterol, heart disease, stroke, asthma or chronic obstructive pulmonary disease. We also recorded self-reported medicine use for those who reported a chronic health condition, to permit some validation of the reported chronic conditions.

Body composition

Height (with SECA 214 stadiometer, http://www.seca.com), weight and body fat percentage (BFP; using the Omron fat analyser scale HBF-356, http://www.omron-healthcare.com.sg) were measured by trained interviewers following standard protocols. BMI was calculated as weight (kg) divided by the square of height (m^2). Two definitions of obesity, based on BFP or BMI, were used in the present study. Obesity by BFP was defined as ≥25 % (males) and ≥35 % (females). Obesity by BMI was defined as ≥30 kg/m^2.

Other statistical analyses

A comparison of self-reported chronic conditions and self-reported medication use indicated that 95 % of the people reporting a chronic condition were taking medication(s) that corresponded to that condition. Subsequent analyses comparing activity levels to chronic conditions were restricted to this sub-set of participants.

Outliers with ActiGraph counts per minute (≥ median + 1·5 × interquartile range) were removed (n 617) before the cluster analysis[32]. Outliers did not differ in terms of demographic variables (all $P > 0{\cdot}05$). For interval-scaled variables such as age and BMI, independent t tests were used to compare the differences between clusters and Cohen's d[33] was used to assess the effect size of these differences. Effect sizes of 0·2, 0·5 and 0·8 were classified as small, medium and large, respectively[33]. For categorical variables, Pearson's χ^2 test was used to compare the differences between clusters. For the prevalence of chronic health conditions, odds ratios, unadjusted and adjusted for age, sex, smoking, education and income, were used to compare the differences between clusters. All statistical analyses were performed using Predictive Analytics SoftWare (PASW 18·0, formerly known as SPSS).

Results

Cluster analysis

Analysable accelerometer data were obtained from a total of 1740 participants. The average of 1128 correlations for the forty-eight hourly variables was 0·09. Among those, only nine pairs (0·8 %) had a correlation larger than 0·5, ruling out multicollinearity among the forty-eight variables. A four-cluster solution was obtained using both the elbow method and the dendrogram (Fig. 1). It showed that, when the number of clusters increased from two to four, the within-cluster sums of squares were large. However, two clusters had a sample size of twenty or less. Upon further examination, one cluster (n 20) showed constant PA for the entire 24 h period, evidently an error; and the other included only six people. These twenty-six participants were removed, leaving 1714 participants, 480 (28 %) in cluster 1 (the 'active') and 1234 (72 %) in cluster 2 (the 'less active'). We did not find groups of people who were active only on the weekend but not during the week (or vice versa), which if present would have formed other distinct clusters. The pseudo R-square and Mann–Whitney U test z-values for each of the forty-eight hourly variables ranged from 0·01 % to 19·92 % (mean 7·57 %) and from 0·26 to 17·54 (mean 8·71), respectively. Thirty-five out of the forty-eight Mann–Whitney U tests were significant at the 5 % level.

Cluster physical activity profile

Figures 2 and 3 show weekday and weekend PA patterns, respectively, for the two clusters, as well as the average level. First, with respect to the overall PA patterns (solid lines in Figs 2 and 3) there was a slightly greater hourly variation on weekdays than on weekends. Slight increases in counts per minute were observed on weekdays during 08.00–08.59, 13.00–13.59 and 18.00–18.59 hours, most likely corresponding to times of commuting to and from work, and going to lunch. On weekends (Fig. 3, solid line), the overall PA trend was comparatively smooth between 11.00 and 18.59 hours.

Second, on weekdays, both clusters showed similar temporal PA patterns, differing only in intensity. By contrast, the two groups showed different patterns on the weekend. For cluster 1, activity peaks were found at 10.00–10.59, 16.00–16.59 and 19.00–19.59 hours, suggesting periods of increased PA. For cluster 2, the hourly PA curve on weekends was low and smooth, suggesting no increased PA or sports activity. In sum, participants of cluster 1 were generally more active and showed a more varied PA pattern on weekends than those of cluster 2.

PA levels are summarized in Table 1. The overall average count per minute was 310·9. The participants spent 22·5 and 247·5 min/d on MVPA and on LPA, respectively. Participants were in general more active on weekdays than on weekends (323·6 $v.$ 297·2 counts/min). They also spent slightly more time on MVPA on weekdays

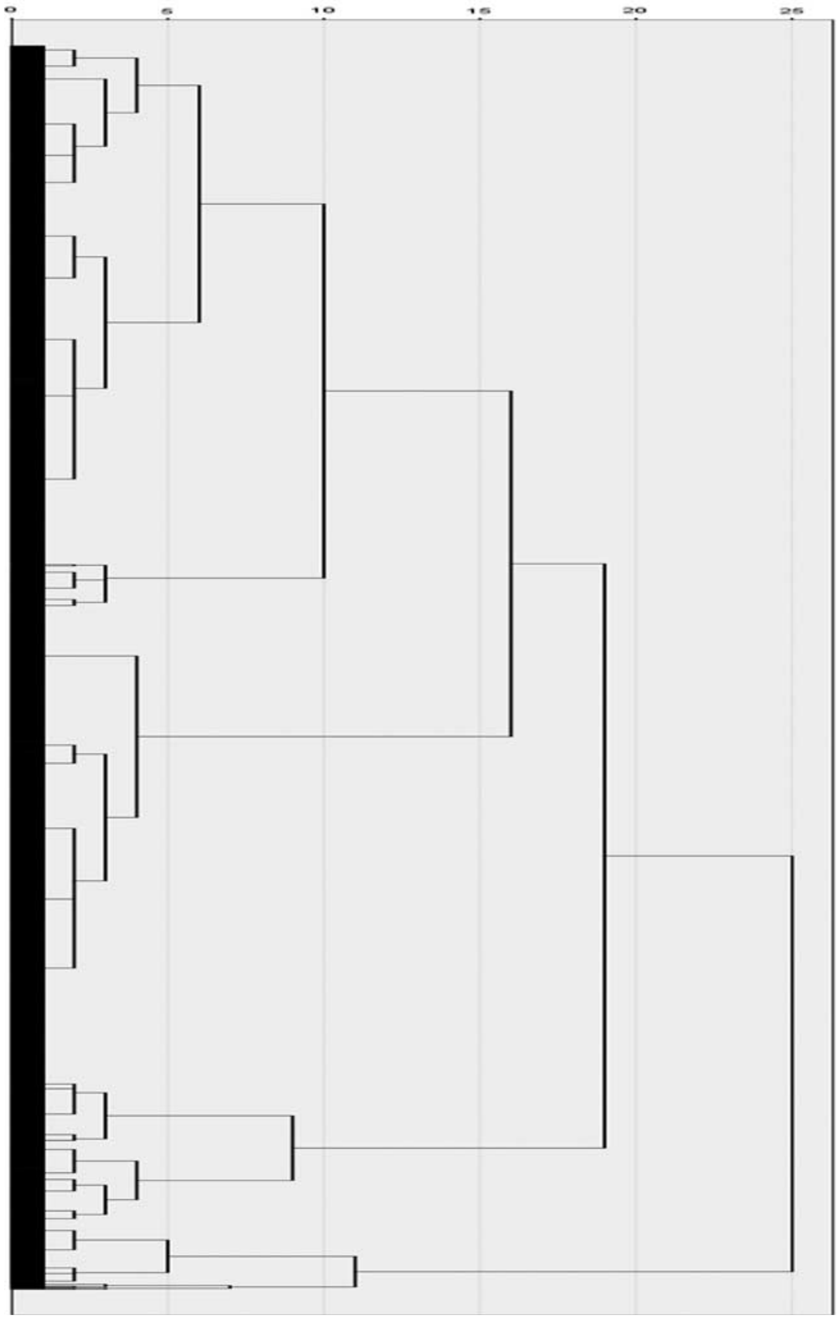

Fig. 1 Dendrogram of the cluster analysis solution

than on weekends (23·1 *v.* 20·9 min/d) and less time on LPA on weekdays than on weekends (242·1 *v.* 260·9 min/d). These differences were observed among participants in both clusters.

There were large differences between the two clusters in terms of counts per minute (456·4 *v.* 252·0 counts/min, $d = 1·62$), daily MVPA minutes (35·4 *v.* 17·5 min/d, $d = 1·28$) and daily LPA minutes (319·0 *v.* 219·7 min/d, $d = 0·82$). An active participant (accumulating 150 min MVPA/week as recommended by the Centers for Disease Control and Prevention/American College of Sports Medicine)[11] had 4·18 times the odds (95 % CI 2·75, 6·37) of being in the active cluster.

Demographic profiles of the clusters

Table 2 shows that people in the active cluster were heavier and had lower BFP than those in the less active cluster. After adjusting for sex, however, there was no difference in BFP between the two clusters. Compared with the less active group, males in the active group had lower BFP (22·3 % *v.* 23·5 % in the less active group, $P < 0·05$), were shorter (165·0 cm *v.* 167·3 cm in the less

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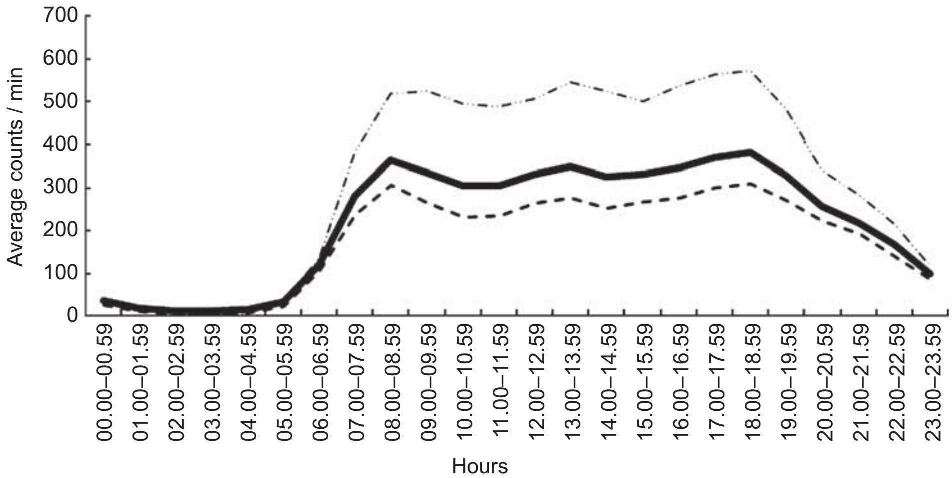

Fig. 2 Hourly physical activity pattern in the FAMILY Project Cohort Study, Hong Kong, 2009 (weekdays): ——, overall; – · · · – · · · –, cluster 1 (active); – – –, cluster 2 (less active)

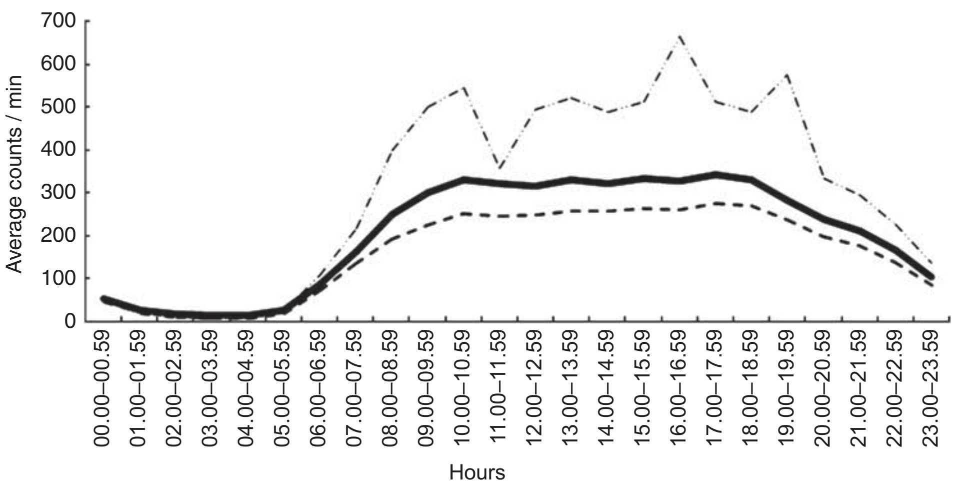

Fig. 3 Hourly physical activity pattern in the FAMILY Project Cohort Study, Hong Kong, 2009 (weekends): ——, overall; – · · · – · · · –, cluster 1 (active); – – –, cluster 2 (less active)

Table 1 Summary of physical activity levels of the 1714 participants in the FAMILY Project Cohort Study, Hong Kong, 2009

	Overall (*n* 1714)		Cluster 1 (active; *n* 480)		Cluster 2 (less active; *n* 1234)		
Variable	Mean	SD	Mean	SD	Mean	SD	Effect size
PA counts/min (overall)	309·2	125·1	456·4†††	116·0	252·0	69·2	1·62
PA counts/min (weekday)	323·6***	147·8	470·4***,†††	144·4	266·5***	103·1	1·37
PA counts/min (weekend)	297·2	140·1	443·2†††	144·3	240·5	87·7	1·44
Effect size	0·21		0·23		0·38		
MVPA min/d (overall)	22·5	14·0	35·4†††	15·7	17·5	9·3	1·28
MVPA min/d (weekday)	23·1***	15·9	35·9*,†††	18·7	18·1***	11·2	1·12
MVPA min/d (weekend)	20·9	15·3	33·9†††	17·8	15·8	10·5	1·18
Effect size	0·16		0·13		0·25		

PA, physical activity; MVPA, moderate-to-vigorous physical activity.
Mean values were significantly different from those at the weekend: $*P<0·05$, $***P<0·001$.
Mean values were significantly different from those of cluster 2: $†††P<0·001$.

active group, $P<0·05$) and younger (41·2 years *v.* 44·3 years in the less active group, $P<0·05$), but these differences were not found among females.

The demographics of the participants (Table 3) were similar to those of the Hong Kong population (46·0 % male; 39·7 % had an income lower than $HK 10 000;

Table 2 Age and body composition measurements for the 1714 participants in the FAMILY Project Cohort Study, Hong Kong, 2009

	Overall (n 1714)		Cluster 1 (active; n 480)		Cluster 2 (less active; n 1234)		
Variable	Mean	SD	Mean	SD	Mean	SD	Effect size
Age (years)	43·2	16·4	42·1	14·9	43·7	17·0	−0·10
Weight (kg)	60·4	12·9	61·4†	13·1	60·0	12·9	0·11
Height (cm)	160·5	9·3	160·8	9·8	160·5	9·1	0·03
BMI (kg/m^2)	23·8	3·8	24·1	3·8	23·7	3·9	0·11
BFP	26·9	8·1	25·6†	8·2	27·4	8·1	0·22

BFP, body fat percentage.
Mean values were significantly different from those of cluster 2: †$P < 0·05$.

Table 3 Demographic and lifestyle characteristics of the 1714 participants in the FAMILY Project Cohort Study, Hong Kong, 2009

			Cluster 1 (active; n 480)		Cluster 2 (less active; n 1234)	
Variable	Category	Overall (n 1714)	n	Column %	n	Column %
Age group, years ($\chi^2 = 32·94$†††)	15–24	264	66	13·8	198	16·0
	25–34	224	58	12·1	166	13·5
	35–44	352	115	24·0	237	19·2
	45–54	454	156	32·5	298	24·1
	55–64	258	63	13·1	195	15·8
	≥65	162	22	4·6	140	11·3
Sex ($\chi^2 = 35·82$†††)	Male	788	276	57·5	512	41·5
	Female	926	204	42·5	722	58·5
Education level ($\chi^2 = 8·25$)	Primary school	282	83	20·6	199	19·7
	Secondary school	788	233	58·0	555	54·8
	Post-secondary school	122	38	9·5	84	8·3
	University level	222	48	11·9	174	17·2
	Missing§	300	78	–	222	–
Smoking ($\chi^2 = 7·63$†)	Yes	184	68	16·8	116	11·5
	Had quit	60	18	4·5	42	4·1
	No	1173	318	78·7	855	84·4
	Missing§	297	76		221	
Drinking ($\chi^2 = 1·66$)	Yes	437	137	34·0	300	29·7
	Had quit	32	9	2·2	23	2·3
	No	944	257	63·8	687	68·0
	Missing§	301	77	–	224	–
Monthly personal income, \$HK‡ ($\chi^2 = 39·20$†††)	1–5000	472	93	24·0	379	39·0
	5001–10 000	293	116	30·0	177	18·2
	10 001–15 000	230	76	19·6	154	15·8
	15 001–20 000	127	39	10·1	88	9·0
	>20 000	238	63	16·3	175	18·0
	Missing§	354	93	–	261	–
Physical activity required at work ($\chi^2 = 143·50$†††)	No full-time job	478	88	21·9	390	38·6
	Not physically demanding	458	90	22·4	368	36·4
	Somewhat physically demanding	315	128	31·8	187	18·5
	Physically demanding	133	76	18·9	57	5·6
	Very physically demanding	28	20	5·0	8	0·8
	Missing§	302	78	–	224	–

Significant differences between the two clusters: †$P < 0·05$, †††$P < 0·001$.
‡\$US 1 = \$HK 7·8.
§Missing values are not included in column percentages.

22·7 % attained only primary education, while 18·0 % had a bachelor's degree or above). Table 3 shows that the two clusters differed in age group, sex, smoking, income and PA required at work. The active cluster had a higher proportion of middle-aged participants (ages 35–54 years), while the proportions of adolescents and the elderly were higher in the less active cluster. There were more males (57·5 %) in the active cluster and more females (58·5 %) in the less active cluster. The proportion of smokers was higher in the active cluster (16·8 % *v.* 11·5 % in the less active cluster, OR = 1·55, $P < 0·001$). Classifying smokers by sex, it was found that the proportion of males who smoked was higher in the active cluster than in the less active cluster (26·4 % *v.* 19·0 %, OR = 1·53, $P < 0·001$), while for female smokers this pattern was reversed (3·1 % *v.* 4·4 %, OR = 0·70, $P < 0·05$). Monthly personal income groups (in Hong Kong dollars; \$US 1 = \$HK 7·8) were differently distributed in the two clusters, particularly in

Table 4 Prevalence (%) of chronic health conditions and obesity in the FAMILY Project Cohort Study, Hong Kong, 2009

	Prevalence (%)					
	Cluster 1 (active; n 480)	Cluster 2 (less active; n 1234)	OR‡	95 % CI	Adjusted OR‡,§	95 % CI
No chronic health condition	81·82	72·67	0·59	0·45, 0·78	0·62	0·46, 0·84
Chronic health conditions						
Cancer	0·45	1·55	3·45	0·80, 14·94	3·37	0·71, 16·04
Diabetes mellitus	4·09	5·26	1·30	0·76, 2·23	1·35	0·77, 2·38
High blood pressure	10·00	14·14	1·48	1·04, 2·11	1·21	0·82, 1·79
High cholesterol/TAG	6·14	10·09	1·72	1·11, 2·65	1·52	0·96, 2·42
Heart disease	0·68	2·07	3·08	0·92, 10·27	2·54	0·71, 9·16
Stroke	0·23	1·03	4·59	0·60, 35·40	3·97	0·50, 31·71
Asthma	0·68	2·33	3·47	1·05, 11·50	4·48	1·02, 19·65
COPD	0·91	0·69	0·76	0·23, 2·53	1·29	0·32, 5·24
Obesity‖						
BFP	37·13	43·79	1·32	1·04, 1·67	1·12	0·87, 1·44
BMI	7·20	6·32	0·87	0·55, 1·37	0·89	0·55, 1·42

COPD, chronic obstructive pulmonary disease; BFP, body fat percentage.
‡Reference category for the odds ratio: cluster 2.
§Adjusted for age, sex, smoking, education and income.
‖Indicators of obesity: BFP ≥25 % (males), ≥35 % (females); BMI ≥ 30 kg/m^2.

lower-income brackets. In the active cluster, 24·0 % and 30·0 % of the participants were in the \$HK 1–5000 and \$HK 5001–10 000 group, respectively, while in the less active cluster these numbers were 39·0 % and 18·2 %, respectively (OR = 0·74 and 1·93, both $P < 0·001$). Finally, more participants had physically demanding jobs in the active cluster than in the other cluster ($P < 0·001$).

Health profile of the clusters

The odds of having any of the eight chronic conditions in the less active cluster was 1·62 times (= 1/0·62) that in the active cluster (95 % CI 1·20, 2·20), adjusted for age, sex, smoking, education and income (Table 4). The odds of having been diagnosed with cancer, diabetes, heart disease, stroke or asthma for the less active cluster were more than twice those for the active, although statistical significance was observed only for asthma ($P = 0·049$). The prevalence of obesity was similar in both clusters regardless of the criterion used to define obesity (Table 4).

Discussion

We identified two temporal PA patterns in this Hong Kong population by using cluster analysis on hourly accelerometer data. The active cluster had higher overall PA levels than the other and a distinctive weekend PA pattern with clear peaks at certain hours. In contrast, the less active cluster had similar temporal patterns on weekdays and weekends. The two clusters differed in counts per minute by 204·4 (the equivalent of daily PA of an American woman aged 60 years or above)[17].

In summary, middle-aged people, males, smokers, the middle-income group and those having physically demanding jobs were more likely to be in the active cluster, consisting of one-quarter of the sample. These clear differences in demographic characteristics between the two clusters are discussed as follows. First, middle-aged participants, aged 35–54 years, were prominently represented in the active cluster, whereas the less active cluster had more of the younger and older participants (ages 15–34 years and ≥55 years). The variable age distribution of the less active group suggests a need for different approaches in developing age-specific intervention programmes. A similar age difference was found in an accelerometer study of PA in the USA, in which those aged 40–49 years were the most active group[34]. This may reflect the pandemic of sedentary lifestyles (e.g. screen time) among adolescents worldwide. Second, and surprisingly, in our sample the proportion of male smokers was higher in the active than in the less active group, contrary to a previous study in China[16]. This is because smokers were more likely to have physically demanding jobs than non-smokers. In the present study, 18·5 % (= 34/184) of the smokers had a physically demanding job, compared with 10·1 % (= 118/1174) among non-smokers. Third, the income distribution was significantly different between the two clusters. In particular, the proportion of lower-income groups was higher in the less active cluster than in the active cluster. A possible explanation for this is that a large proportion of females (346/777 or 44·5 %) were in lower-income brackets, and they may be housewives with part-time jobs (169/346 or 48·8 % of them had full-time jobs) and less time for exercise or sports activities. In addition, it is possible that some males (19·2 % = 118/614) in the low-income group of \$HK 5001–10 000 may have shorter workdays (hence a lower chance of working on weekends) that allows them to exercise on weekends. Fourth, the proportion of participants having a physically demanding job was significantly higher in the active cluster than in the less active cluster. This finding further

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supported the cluster solution as participants with a physically demanding job were in general more active than those with a less physically demanding job during weekdays (392·5 *v.* 289·2 counts/min, $P < 0·001$).

The two clusters did not differ regarding other demographic variables, some of which had previously been reported to be associated with PA levels. One such variable was education: lower education level was associated with lower PA level among US and Swedish males[10] and Chinese adults[16], but not in our sample. This was perhaps because PA in Hong Kong is mostly not in the form of choosing to exercise for personal fitness, but is more related to the virtually universal use of public transportation (which always involves some walking). Another such variable was BMI[10,16]. Other studies of PA pattern, mostly among children, found that higher BMI was associated with lower PA levels[8,21,35–37]. This association was not found in our study, again perhaps because much of the PA in Hong Kong relates to routine transportation that is undertaken regardless of body weight. The other inconsistency regarded alcohol usage. Alcohol consumption has been linked to higher PA level among adults[38] and college students[39] in the USA, but there was only a non-significant difference in our sample.

Strengths and limitations

The present study offered a large sample from a Westernized and urbanized Asian population that complements the picture obtained from existing studies in European and North American samples. It used cluster analysis to analyse accelerometer data, with which we could identify PA patterns that are specific to certain times of the day.

A limitation of the study concerned sample representativeness. While it began from a random population sample, the inclusion criteria required at least 12 h of recorded time daily for four consecutive days, which entailed some loss of respondents and a potential selection bias. It is likely that the PA patterns for those who provided four valid days of accelerometer data were different from those who do not. While the study provides useful descriptive data, its major limitation lies in the cross-sectional design. The association of PA with chronic health conditions cannot demonstrate causality, as chronic conditions could have limited the ability to exercise[40]. Nevertheless, the findings regarding the association of PA with chronic health problems are important, as they may raise the priority of promoting PA among those with chronic health conditions.

Conclusions

The present study has broadened the scope of research on PA patterns and shed light on the potential of using accelerometer data and PA patterns to classify individuals in more precise categories, e.g. active on weekends, sedentary in the morning, etc. It has also contributed to the understanding of PA patterns of Hong Kong Chinese, the most Westernized and urbanized city of China, by identifying two clusters, one more active than the other. Neither cluster showed signs of regularly increased PA (implying exercise or sports activity) on weekdays, most probably reflective of the intense pace in city life. Therefore, we suggest that potential interventions to promote PA in Hong Kong may be most effective in targeting those who are sedentary on weekends. Providing free weekend PA programmes may also help increase participation rates. Further research is needed to refine the classification of PA patterns and establish standard cut-off points. Also, future study is needed to examine the predictive power of different PA patterns on long-term health outcomes.

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