Original Paper

~~Cross-sectional study on c~~Clusters of adolescent physical activity tracker patterns and its associations with physical activity behaviours in Finland and Ireland: A cross-sectional study

Abstract (361/450 words)

Background: Physical activity trackers (PATs), such as applications (Apps) and wearable devices (e.g. sport watches and heart rate monitors), are increasingly being used by young adolescents. Despite the potential to monitor and improve moderate-to-vigorous physical activity (MVPA) behaviours, there is a lack of research that confirms an association between PATs ownership or use, and physical activity (PA) behaviours at a population level.

Objective: The purpose of this study was to examine ownership and use of PATs in youth, and the associations with PA behaviours including daily MVPA, sport club membership and active travel, in two nationally representative samples of young adolescent males and females in Finland and Ireland.

Methods: Comparable data were gathered in the Finnish School-aged Physical Activity (F-SPA 2018; n=3311) and the Irish Children's Sport Participation and Physical Activity (CSPPA 2018; n=4797) studies. A cluster analysis was performed to obtain the patterns of PATs ownership and usage by adolescents (age 11y –15y). Four similar clusters were identified across Finnish and Irish adolescents: 1) no PATs, 2) PATs owners, 3) Apps users, and 4) wearable device users. Adjusted binary logistic regression analyses were used to evaluate how PATs clusters were associated with PA behaviours, including daily MVPA, membership of sport clubs and active travel, after stratification by gender.

Results: The amount of Apps ownership among Finnish adolescents (61.5%) was almost double that of their Irish counterparts (36.2%). Apps users were more likely to take part in daily MVPA (males: OR=1.27, CI=1.04-1.55, females: OR=1.49, CI=1.20-1.85), be members of sport clubs (males: OR=1.37, CI=1.15-1.62, females: OR=1.25, CI=1.07-1.50), compared to no PATs cluster, after adjusting for country age, family affluence and disabilities. These associations, after the same adjustments, were even stronger for wearable device users to participate in daily MVPA (males: OR=1.83, CI=1.49-2.23, females: OR=2.25, CI=1.80-2.82), be members of sport clubs (males: OR=1.88, CI=1.55-.288, females: OR=2.07, CI=1.71-2.52). ~~Apps and wearable device users were, respectively, more likely to take part in daily MVPA (males: OR=1.27, CI=1.04-1.55; OR=1.83, CI=1.49-2.23; females: OR=1.49, CI=1.20-1.85; OR=2.25, CI=1.80-2.82), be members of sport clubs (males: OR=1.37, CI=1.15-1.62; OR=1.88, 1.55-2.28; females: OR=1.25, CI=1.07-1.50; OR=2.07, CI=1.71-2.52), compared to no PATs cluster, after adjusting for country, age, family~~

Significant associations were observed between male wearable device users and taking part in active travel behaviours (OR=1.39, CI=1.04-1.86).

Conclusions: Although Finnish adolescents report more ownership of PATs than Irish adolescents, the patterns of use and ownership remain similar. PA behaviours were positively associated with wearable devices users and Apps users. These findings were similar between males and females. Given the cross-sectional nature of this data, the relationship between using Apps or wearable devices and enhancing PA behaviours remains unclear.

Trial Registration: Not necessary

Keywords: Wearables; children; activity trackers; active travel; organised sport; self-quantification

Introduction

Physical inactivity is one of the leading causes of worldwide mortality. There is an urgent need to understand how to increase physical activity (PA) participation levels among young adolescents (typically aged between 11y-15y olds). The habits developed during early adolescence can lead to behaviours during adulthood [1], particularly for PA, in both the short- [2,3] and long-term as adults [4,5]. As technologies have evolved in the last generation, less is known about how physical activity trackers (PATs) use in young adolescents are used in relation to PA behaviours. Lee and colleagues [6] conducted a scoping review, and included 14 studies that comprised of interventions that included websites, applications (Apps) and wearables devices. Apps and wearable devices include the interaction of sensors that have the capability to measure PA, and for the purpose of this study, they are referred throughout as PATs. Small to medium effect sizes in adult studies were demonstrated, specifically when individuals used the PATs information to modify their behaviour and increase their PA levels [7], however, intervention studies among adolescents are rare [6]. These low number of adolescent studies may be attributed to the way Apps and wearable devices have been designed primarily with the adult population in mind, leading to low levels of use among adolescents [8]. Even though there have been recent developments for companies to build PATs for youngsters, the feedback from children through their parents still indicate that design issues are present and can cause a barrier for sustainable use [9]. Understanding the association between PATs ownership and use may help inform their use as an effective intervention tool in the young adolescent population.

Country specific usage

The use of Apps requires the use of smart phones and consistent internet connectivity. In Ireland, the prevalence of mobile phone use by 13y olds were already at 98% [10] with 54% reporting to use the internet with their phones [11].

Whereas, by the time Finns adolescents are aged 16y, 93% use their mobile phone to access the internet and this has been facilitated by the way mobile phone subscription plans in Finland typically offer unlimited data [12].
According to EUROSTAT, 94% of homes in Finland have access to the internet, whereas, in Ireland, internet household accessibility stands at 89%, which is equivalent to the average in European Union countries [13].
In Finland, wearable devices are used in 22% of households [12], although data in Ireland has not been reported previously. Younger generations often report greater use of the internet than the average population [14], and this is frequently used to ensure that PATs functionality are optimal for age-appropriate usage.
Both countries perform highly in terms of progression in making societies mediated by digital technology. For examples, out of all OCED countries, Finnish users use the most amount of mobile data per subscriber (OECD, 2018), and the country has been ranked the highest for digital services in all of Europe [15]. Ireland on the other hand is the second ranked country in Europe, outside of the Nordic countries, in the digital economy and society index (DESI)[13]. One of the major differences between Finland and Ireland is the human capital. Ireland is ranked number 1 in terms of open data usage; however, the country is placed 21st in the EU for eHealth services, with just one in ten people (11%) using it. Whereas in Finland it tops that eHealth services index, with 49% of individuals using it [15].

PATs for facilitation of PA behaviours

Emerging evidence suggests that PATs have a positive effect on PA behaviours, particularly as facilitators, rather than drivers of health behaviour change [16].
From the end users perspective, one significant limitation of commercial PATs products is the short life cycle [17,18]. It has been estimated that 10% of the global population use fitness Apps, but only 2% are paying users [19]. These figures have grown in previous years, and are expected to increase by 4.5% every year, at least until 2024 [19]. Despite the commercial growth in the market, the expected level of success of PATs ownership in terms of PA behaviour change is yet to be fully interrogated or proven. Most of the functions within Apps include between five and eight behavioural change techniques, with goals and planning, feedback and monitoring, social support and shaping behaviour, commonly featured [20]. Several trials have investigated the efficacy of PATs to increase PA levels, and often, although an initial increase in PA level is documented, these changes are not sustained long-term [18,21,22], or could not be replicated with younger populations [23]. High attrition levels are particularly common for PATs, where the novelty effect wears off and so does the usage and effectiveness [24]. Designers of PATs could be partly responsible for this attrition, as the products made may not be sufficiently accurate enough for the demands of the end user [25,26] or the automated systems for providing reminders and feedback are deemed inadequate [27]. The majority of features of PATs, include features that can be used for socialising between the users, which is important for younger adolescent populations [9]. Despite this, young adolescents have reported that the PATs offerings currently do not provide enough customisation or personalisation [8].

Moreover, young adolescents see the benefits of multi-purpose devices, as this can help the individual track various aspects of their life, such as health [28]. Differences have been observed in the way that males and females use the multiple functions of PATs. For example, adolescent males prefer to socialise with their PATs through 'banter' and other friendly conversations [29]. Female PATs users report lower levels of aspirations to take part in competitive sport than males [30], which may translate into less use of the goal and planning functions [31], areas commonly used in optimal performance in sport [32]. Feedback from PATs is also central to control theory [33], as it confirms user performance to prompt further behaviours. For the purpose of this study, we focused on the association between PATs ownership and use and three behaviours, 1) overall PA behaviours, 2) participation in sport clubs, and 3) active commuting. Research in PATs to act as an intervention for adolescents is limited [8], and to the authors' knowledge, only a handful of observational studies have been published on PATs usage in young adolescents [34]. Therefore, the purposes of this study were to investigate the differences in PATs ownership and usage between Finnish and Irish adolescents, while investigating the association between PATs ownership and self-reported PA behaviours in both cohorts and considering the potential influence of gender.

Methods

Recruitment

Data for this cross-sectional study were collected in Finland and Ireland during the first half of 2018. Both the Finnish and Irish data were collected from national representative cross-sectional studies. In Finland, the Finnish School-aged Physical Activity (F-SPA) study [35] is the national PA monitoring study for children and adolescents (LIITU in Finnish) and the Irish equivalent is the Children's Sport Participation and Physical Activity (CSPPA) study [36].

The F-SPA 2018 was based on two level cluster analyses [35] and is an extension to the F-SPA 2014 and F-SPA 2016 studies, by including students as young as 7y olds. A parallel study took place for special education classes and schools (SECS), hence sampling did not include special education schools. Probability proportion size was used to calculate primary sampling unit to generate a nationally representative sample. A total of 311 schools (Finnish schools: 86%, Swedish schools: 14%) and 9940 students altogether.

The CSPPA 2018 was a follow up and extension to the original 2010 study [37]. CSPPA 2018 included schools from both the Republic of Ireland and Northern Ireland. The sampling frame for the schools involved in CSPPA 2010 included all schools with students age between 10y – 18y olds in the Republic of Ireland. A systematic one-stage cluster sampling method was used for CSPPA 2010 and schools were stratified by four criteria (school gender, school socio-economic status, school location and school size). The same schools in 2010 were invited again to take part in 2018, and a replacement list based on creation of an equivalence sample was made to ensure sufficient number of students were included to allow for study design effects. Schools from Northern Ireland were not

part of CSPPA 2010 and all mainstream schools from Northern Ireland were included in the sampling frame for CSPPA 2018. Special schools, junior-only schools and colleges of further education were excluded from the database. In total, between the Republic of Ireland and Northern Ireland, 115 schools were included in the overall study sample and 6,651 students took part in CSPPA 2018.
All surveys were completed on either a tablet, laptop or PC, in the students' own classroom and under the supervision of teachers in F-SPA 2018 or specifically trained research assistants in CSPPA 2018. Students who were given permissions by their parents or guardians had a right to withdraw from the study at any time. Completion of the survey was done anonymously and voluntarily. The Finnish study was approved by the Ethical committee of the University of Jyvaskyla, Finland, and the Irish study was approved by the Ethical committee of the University of Limerick, Ireland.

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For the purpose of comparisons between the studies, only responses from young adolescents aged between 11y-15y olds were included (Finland N=3311, Ireland N=4797) in the final data set. Variables for the country data files were relabelled to allow for merging in IBM SPSS 25.0. Details of the measures in both surveys used for this study is reported in Appendix Table 1.

Measures

Both surveys collected demographic information on gender, age, disability status, and self-reported socioeconomic status, via the Family Affluence Scale (FAS) [38]. The CSPPA 2018 study also included the option of 'other' to respond to the gender, whereas the F-SPA 2018 did not, therefore respondents with 'other' (n=69; 1.0%) were removed from the CSPPA 2018 sample, prior to analysis.
Items of PATs had slight variation (Appendix Table 1). In Finland, a block question was designed to keep the survey length to a minimum. The opening question was, "How often in a week do you use the following physical activity tracking device?" with the following options, "mobile apps", "activity meter or sport watch", and "heart rate monitor". The item was used in the previous edition of the Finnish monitoring study [34]. Although the response options were updated, based on feedback from the test-retest reliability study [39] whereby the previous three categories of 'none', 'own but do not use' and, 'own and use' were extended to a six item category frequency scale of 1) I don't have, 2) Never, 3) At least once a week, 4) Once a day, 5) More than once a day, 6) All the time. The variables were divided into three groups to match with the previous reporting, whereby respondents to 1 were grouped as 'do not have', 2 were grouped to 'own but do not use', and 3 to 6 were grouped to 'own and use'.
The Irish version had separate questions on ownership, use and frequency of use for 1) physical activity apps, 2) smart watches, 3), heart rate monitors, 4) pedometers and 5) other device. For comparison purposes, individuals who responded to only having a pedometer or other device (n=528; 11.0%) were recoded as not having a PATs since this was not compatible between the two studies. There was a slight variation in the frequency of use of the PATs, whereby the question was, "How often do you use your PATs during a typical week" with response options including, 1) Never, 2) Once, 3) Sometimes, 4) Almost every day, 5) Every day. Responses of

Never were grouped into "own but do not use', and 2 – 5 were grouped to 'own and use'. Null responses to the ownership were deemed as 'do not have'.
Other survey responses used included the self-reported number of days of at least 60 minutes of moderate-to-vigorous physical activity (MVPA) participation, in both 2018 F-SPA and CSPPA studies. The CSPPA 2018 study included two items based on the past 7 days and the usual week. The two items were summed and divided by two and rounded up, whereas the F-SPA 2018 item included one item based on the past 7 days. Previous studies suggest that an average between previous week and the usual week can give a more accurate recall of PA behaviours [40], however in other international surveys, a single item is used to keep reduce the number of items in the survey [41]. Both surveys used the same explanation to define MVPA, as comparable to international study protocol [42]. The PA survey item was then dichotomised into meeting the guidelines (specifically when the respondents reported a total 7 days) and not meeting the guidelines (specifically when the respondents reported anything between 0-6 days). This PA survey item has been previously tested for validity use against accelerometers with young adolescents [40,43] and within test-retest environments [44,45].
Respondents provided details of their mode of transport to school, with 1) walking or 2) cycling categorized as 'active commuters'. Motorised transport included options such as getting a lift by parents or taking the bus. The distance between the primary home and school was also asked. To ensure that reasonable distances plausible for active transport, the Finnish legislation for the provision of free transport costs were set at distances over 5km was used as a cut-off point to differentiate between people who were close (within 5km) and far (over 5km). For the inferential statistics regarding active commuting, only respondents who lived within close range (5km) of the school were included. Therefore, living over 5km was an exclusion criterion for analyses in relation to active commuting.

Statistical Analysis

Descriptive statistics of the population characteristics were produced by Chi-square tests of independence for gender, after stratifying for country. The test of independence between countries were also tested through Chi-square, after consideration of gender.
A two-step approach was used to describe the phenomenon of PATs ownership and use among young adolescents in Finland and Ireland. The amount of possible combinations of PATs habits was investigated using cluster analysis to the fewest amount of clusters, yet attempting to retain a meaningful structure (i.e. values of the average silhouette width defining the cluster quality as 'good' (exceeding 0.5) [46]. When the sample was pooled, three clusters were deemed to be sufficient; however, when the test of clusters were examined for each country, one of the clusters in each country had different features, therefore, an extra cluster was added. The characteristics of the four clusters were then tested in the pooled sample, and individually for each country had achieved good cluster quality (Finland silhouette width = 0.6, Ireland silhouette width =0.7) and led to four clusters being identified. The first cluster (and reference category for regression analyses)

included individuals who reported no ownership of Apps, Smart watches or Heart Rate Monitors (HRM). This category was labelled as "no PATs". The second cluster predominately included individuals who reported ownership, but not usage of PATs and were labelled as "PATs owners". The third cluster was labelled as "Apps users" as the majority of Apps users belonged in this cluster, with none in the cluster reported use of smart watches or HRM. The fourth cluster included a mixture of individuals consistently using smart watches and HRM, and were subsequently labelled "wearable device users".
Chi-square tests were used to assess the statistical significance of gender, age groups, FAS and disability for the clusters, and used the Kruskall-Wallis with pairwise comparisons to assess the statistical significance of differences in the average number of days reporting 60 minutes of MVPA for each country.
The binary logistic associations of the meeting the PA guidelines (7 days vs. <7 days – reference category), being an active traveller (cyclist and walker vs. motorised transport who live within 5km of the school – reference category), and organised sport participant (sport club member vs not active in sport clubs – reference category) with no ownership of PATs as the reference category were investigated. The crude associations for each indicator (Model 1) were assessed before adjusting for age, gender, FAS and disability (Model 2). All statistics were run using IBM SPSS 25.0 for Windows (IBM Corp. Released 2017).

Results

User Statistics

Descriptive statistics are provided in Table 1 with comparisons between and within countries. There were statistical differences between the characteristics of Finnish and Irish young adolescents between the two surveys. The CSPPA study had fewer 11y olds than in the F-SPA, where the latter study participants were more evenly distributed across the varying age groups (Chi-square, p=0.755). There were fewer Finnish (n=3311) than Irish (n=4797) respondents in the final sample (Table 1).

Table 1. Descriptive statistics of the samples by country and gender

		Finland	N=3311		Ireland	N=4797		p
		Male	Female	P	Male	Female	P	
		1610	1701		2370	2427		
		%	%		%	%		
Age				0.810			0.003	0.011
	11	39.0	40.0		17.0	19.3		
	13	28.1	28.0		46.0	48.1		
	15	32.9	32.0		37.0	32.6		
FAS				0.806			0.051	0.085
	Low	24.8	24.4		20.9	21.8		
	Middle	57.4	56.9		59.0	55.7		
	High	17.8	18.7		20.1	22.5		

Disability						0.073					0.656		0.166
	None		89.9		88.0			85.9		85.4				
	Disabled		10.1		12.0			14.1		14.6				
Daily MVPA						<.001					<.001		<.001
	Inactive		64.8		71.3			82.5		88.9				
	Active		35.2		28.7			17.5		11.1				
Transport						0.154					<.001		0.020
	Motorised Close		13.5		12.7			28.7		33.1				
	Active Close		58.1		59.8			24.5		19.0				
	Active Far		5.1		3.6			2.5		1.7				
	Motorised Far		23.3		24.0			44.3		46.1				
Sport Club						0.641					0.043		0.059
	Non-Member		40.5		41.3			35.9		38.8				
	Member		59.5		58.7			64.1		61.2				

Inactive Daily MVPA = 0-6 days of MVPA, Active Daily MVPA = 7 days of MVPA

The estimates of ownership and usage of Apps (p<.001), sport watches (p<.001) and heart rate monitors (p<.001) were different between Finnish and Irish adolescents. In Finland, almost two thirds (61.5%) of young adolescents reported owning or using apps to monitor PA, whereas in Ireland, the majority (63.8%) did not own apps to monitor physical activity (Table 2). Over three quarter of Irish adolescents do not own sport watches and this was a greater estimate than among Finnish adolescents (71.4%, p<.001). Moreover, a quarter (24.4%) of Finnish adolescents reported owning or using HRM which was much higher than in Ireland (8.8%, p<.001).

Table 2. Descriptive statistics of apps, sport watches and heart rate monitors by country and gender

		Finland (n=3311)			Ireland (n=4797)			p
		Male	Female	P	Male	Female	P	
		1610	1701		2370	2427		
		%	%		%	%		
Apps				<.001			<.001	<.001
	Not owned	38.8	38.2		67.6	60.0		
	Do not use	21.2	14.3		11.6	14.3		
	Use	40.0	47.5		20.8	25.7		
Sport Watch				<.001			0.563	<.001
	Not owned	68.6	74.1		77.5	78.4		

	Do not use		17.1		10.9				7.1		6.4				
	Use		14.3		15.1				15.4		15.2				
Heart Rate Monitor							<.001						0.194		<.001
	Not owned		71.4		79.6				90.5		91.9				
	Do not use		18.2		12.0				2.3		2.3				
	Use		10.5		8.4				7.1		5.9				

Clusters analyses

The four clusters were 'no PATs', 'PATs owners', 'Apps users', and 'wearable device users' (Table 3), with a silhouette of 0.7 for cluster quality exceeding the'good threshold of 0.5 [46][44]. The crude percentage of individuals who reported daily MVPA was almost double among wearable device users (30.6%) compared to no PATs (16.3%). There was increasing estimates of sport clubs members from cluster 1 (59.6%), cluster 2 (63.3%), cluster 3 (66.1%) and cluster 4 (69.1%) as well as those involved in active transport increased (Cluster 1=56.2%, cluster 2 = 59.6%, cluster 3 = 61.4%, and cluster 4 = 73.1%).

Table 3. Features of the four clusters from pooled data and crude estimates of behaviours

			Cluster 1		Cluster 2		Cluster 3		Cluster 4
			N=3523		N=677		N=2200		N=1631
			No PATs		PATs owners		Apps users		Wearable device users
			%		%		%		%
Apps									
	None		81.6%		6.1%				12.3%
	Own				34.4%		58.5%		7.1%
	Use						59.6%		40.4%
Smart Watches									
	None		58.2%		1.2%		36.4%		4.2%
	Own				78.4%				21.6%
	Use								100.0%
Heart Rate Monitors									
	None		51.6%		4.2%		32.2%		11.9%
	Own				65.7%				34.3%
	Use								100.0%
Crude %									
	Daily MVPA		16.3		19.2		22.9		30.6
	Active Transport		59.6		63.3		66.1		69.1
	Sport clubs		56.2		59.6		61.4		73.1

MVPA – Moderate-to-vigorous physical activity

Multivariate Analyses Males

In the unadjusted model (Table 4), there were positive associations for daily MVPA (OR=1.56, CI=1.29-1.87; OR=2.16, CI=1.79-2.60), active transport (OR=1.41, CI=1.13-1.77; OR=1.83, CI=1.41-2.36) and members of sport clubs (OR=1.32, CI=1.12-1.56; OR=1.97, CI=1.64-2.36) for male Apps users and wearable device users, respectively. Moreover, owners of PATs were positively associated with active travel (OR=1.40, CI=1.02-1.91). After controlling for country, age, FAS and disabilities, the associations had lower odd ratios and the association for active travel and Apps users was no longer statistically significant (Table 4). Disabilities were also not associated with active travel, whereas as adolescents got older, the less likely they would be involved in PA behaviours. Higher FAS was positively associated with daily MVPA and member of sport clubs, whereas it was negatively associated with active travel. There were more Irish adolescents who were members of sport clubs, but significantly fewer who took part in daily MVPA or active travel.

Table 4. Male Adjusted Odd Ratios and 95% Confidence Intervals without (Model 1) and with (Model 2) confounders for each Cluster

		MVPA7 (1=7 days)[a]			ACT (1=active)[b]			Sport Clubs (1=member)[c]		
		OR	LCI	UCI	OR	LCI	UCI	OR	LCI	UCI
Model 1										
None		REF			REF			REF		
Owners		1.17	0.89	1.53	*1.40*	*1.02*	*1.91*	1.03	0.82	1.29
Apps User		*1.56*	*1.29*	*1.87*	*1.41*	*1.13*	*1.77*	*1.32*	*1.12*	*1.56*
Wearable device user		*2.16*	*1.79*	*2.60*	*1.83*	*1.41*	*2.36*	*1.97*	*1.64*	*2.36*
Nagelkerke r^2		0.026			0.017			0.020		
Model 2										
None		REF			REF			REF		
Owners		1.07	0.81	1.42	1.19	0.84	1.69	1.08	0.85	1.37
Apps User		*1.27*	*1.04*	*1.55*	1.06	0.82	1.36	*1.37*	*1.15*	*1.62*
Wearable device user		*1.83*	*1.49*	*2.23*	*1.39*	*1.04*	*1.86*	*1.88*	*1.55*	*2.28*
Country (IE)[d]		0.46	0.39	0.54	0.26	0.21	0.32	1.44	1.25	1.67
Age (older)[d]		0.69	0.63	0.77	0.59	0.50	0.69	0.68	0.62	0.74

	FAS (higher)[d]		1.22	1.08	1.37		0.78	0.66	0.92		1.39	1.25	1.55
	Disability (with)[d]		0.59	0.45	0.77		1.00	0.74	1.40		0.60	0.49	0.73
	Nagelkerke r^2		0.102				0.217				0.075		

OR – Odds ratios, LCI – Lower 95% confidence interval, UCI – Upper 95% confidence interval, MVPA – daily moderate-to-vigorous physical activity [a](reference = not daily), ACT – Active travel [b](reference = motorised), Sport Clubs [c](reference = not member). FAS – Family Affluence Scale (continuous). [d]Direction of adjustment in brackets. Italics represents statistically significant associations.

Multivariate Analyses Females

In the unadjusted model (Table 5), wearable device users were twice as likely to report MVPA (OR=2.45, CI=2.00=3.02) and be member of organised sports (OR=2.29, CI=1.91=2.74). The associations was not as strong for Apps users, and for active travel, the association was similar between Apps users (OR=1.24, CI=1.01-1.53) and wearable device users (OR=1.28, CI=1.01-1.63). Owners of PATs were more likely to be members of sport clubs (OR=1.31, CI=1.01-1.68) when compared to no PATs cluster. After controlling for country, age, FAS and disabilities, the odds ratios were lower, but the models strength were stronger. There were no significant differences between no ownership or usage of PATs and any cluster of PATs. Females with and without disabilities were not different in terms of MVPA and active travel.

Table 5. Female Adjusted Odd Ratios and 95% Confidence Intervals without (Model 1) and with (Model 2) confounders for each Cluster

		MVPA7 (1=7 days)[a]			ACT (1=active)[b]			Sport Clubs (1=member)[c]		
		OR	LCI	UCI	OR	LCI	UCI	OR	LCI	UCI
Model 1										
None		REF			REF			REF		
Owners		1.21	0.86	1.72	0.92	0.65	1.30	*1.31*	*1.01*	*1.68*
Apps User		*1.61*	*1.32*	*1.96*	*1.24*	*1.01*	*1.53*	*1.21*	*1.04*	*1.40*
Wearable device user		*2.45*	*2.00*	*3.02*	*1.28*	*1.01*	*1.63*	*2.29*	*1.91*	*2.74*
Nagelkerke r^2		0.030			0.005			0.028		
Model 2										
None		REF			REF			REF		
Owners		1.27	0.87	1.84	1.14	0.76	1.72	1.27	0.97	1.66

	Apps User		*1.49*	*1.20*	*1.85*		0.98	0.76	1.25		*1.25*	*1.07*	*1.50*
	Wearable device user		*2.25*	*1.80*	*2.82*		0.91	0.68	1.21		*2.07*	*1.71*	*2.52*
	Country (IE)[d]		0.38	0.31	0.45		0.16	0.13	0.20		1.35	1.17	1.55
	Age (older)[d]		0.55	0.49	0.62		0.50	0.43	0.59		0.62	0.57	0.68
	FAS (higher)[d]		1.19	1.04	1.36		0.85	0.72	0.99		1.57	1.42	1.75
	Disability (with)[d]		1.00	0.76	1.31		1.19	0.89	1.58		0.59	0.48	0.71
	Nagelkerke r^2		0.141				0.320				0.109		

OR – Odds ratios, LCI – Lower 95% confidence interval, UCI – Upper 95% confidence interval, MVPA – daily moderate-to-vigorous physical activity [a](reference = not daily), ACT – Active travel [b](reference = motorised), Sport Clubs [c](reference = not member). FAS – Family Affluence Scale (continuous). [d]Direction of adjustment in brackets. Italics represents statistically significant associations.

Discussion

Principal Results

Apps were owned by approximately two thirds of Finnish adolescents and by one third of Irish adolescents, with more females in both countries owning Apps than males. The estimates of Sport watch ownership or use is 28.6% of young Finns, and 22.0% of young Irish adolescents. Approximately 9% of Finnish adolescents, and 6% of Irish adolescents use heart rate monitors. Despite these differences, the clustering patterns of PATs were similar between countries.

Four cluster patterns for PATs were identified: 1) no PATs, 2) PATs owners, 3) Apps users, and 4) wearable device users. In comparison to individuals in the no PATs cluster, wearable device users had the strongest association with PA behaviours (daily MVPA, sport club member, active travel). The likelihood of taking part in daily MVPA, being a member of a sports club, or travelling to school by foot or bike among females were higher than those found in males, indicating strong positive associations between PATs usage and PA behaviours.

More males than females reported meeting the PA guidelines of daily MVPA for at least 60 minutes per day [47]~~[45]~~. Moreover, approximately twice as many males and two and a half times as many females in Finland reported meeting the daily MVPA guideline (i.e. ≥ 60 minutes), compared to Irish males and females. Finland tends to perform much better than Ireland in studies that report international comparisons of MVPA [48]~~[46]~~, indicating the results of this study aligns with other international level findings. Over two and three times as many Finnish males and females, respectively, took part in active travel to school, compared to Irish adolescents. The differences in membership of sport clubs were not statistically significant between adolescents in the two countries. According to the results of the

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2016 Global Matrix on physical activity, there were similar differences in grades between the two countries [49].
The majority of reports from the adult surveys suggest that there are similarities in the use of PATs between Finland and Ireland [50,51]. However, in this current study there were significantly more Finnish adolescents who owned or used PATs, compared with their Irish counterparts. In 2016, there were approximately 53% of Finnish adolescents aged between 11y-15y olds who reported to own apps [34]; however, from this study (2018 data), the rate of ownership of apps increased to approximately 62%. That is a 9% increase in a two-year period. There were also a notable increase in the ownership of sports watches and heart rate monitors between 2016 and 2018, and this has followed the rate of market penetration in the last two years [19]. This is the first-time that PATs figures from Irish adolescents have been reported, and data would suggest that adolescents reported a higher rate of ownership of apps (36%), when compared to an Irish 18y-24y old cohort (20%) [50]. Based on these growth figures, it may be viable to design interventions using PA apps in Finland currently and in the near future, whereas in Ireland, more adoption is needed for natural experiments or trials to take place, otherwise interventions would need to control the novelty effect of introducing a new wearable [24].

Comparison with Prior Work

PATs and daily MVPA

Both male and female Apps and wearable device users had positive associations with daily MVPA, compared to adolescents with no PATs. Yet the PA behaviours of young adolescents who merely own, but reported to no use PATs was not statistically different from individuals in the no PATs cluster. Some of the underlying reasons for these results can be related to the ownership and usage of PATs as a proxy for readiness for the behaviour [52]. The functions available in PATs can provide regular monitoring [53], self-comparison of previous performances, and setting targets for current performances [9] and these are all deemed to be effective behavioural change techniques, as reported in previous studies [20]. As such, the feedback from PATs to the individual can have an educational benefit to the user [54]. Details of the habits in using PATs need to be explored further to understand the mechanisms of these associations, particularly as individuals introduced to PATs in interventions experience attrition [17], thus limiting the sustainability of behaviour change.

Use of PATs in organised sport

Similar to the associations with MVPA, Apps users and wearable device users were more likely to report membership of sport clubs, when compared to individuals with no PATs. Depending on the features and functionality of the specific PATs that individuals use, young adolescents can share data with other members of the sports club. This may increase motivation among males, as they have been reported to boast about their achievements with their peers [29]. Moreover, PATs could be used to support coaching practices by giving individualised information on athletes'

performance. Data has been used whereby feedback on physiological parameters, such as heart rate can be informative to athletes and could reduce overtraining and thus the risk to injuries [55]. This is certainly a promising area of development within wearable technology, whereby safety promotion and injury prevention features are built in. Seshadri and colleagues [56] further suggest that more non-invasive sensors around the body, such as earrings, headphones, rings and within textiles are needed for wearables to act as a crucial piece of technology in the prevention of injuries. Gabbett [57] argued that training harder can be protective of injuries if done smartly and assisted through trackable data. This may be an important message for the general adolescent population, where health promoters aim to increase levels of physical activity. Through careful planning to build up physical fitness. Not only do individuals have feedback on their own behaviour, as postulated by control theory, the ideas and information for taking part in more physical activity can be supported by the environment of sport clubs, typically the youth sports coach.

Active travel and PATs

After adjusting for country, age, family affluence and disabilities, the only significant association observed was between male wearable device users and active travel. Although there are studies that suggest PATs can help support more walking [21,27], previous studies have been based primarily on adults and the active travel behaviours of young adolescents can be heavily influenced by their parents [58]. Furthermore, distances between home and school that were considered as too far were over 4km (2.5miles) in Ireland [59] and a large reduction in active commuters from Finnish young adolescents who lived 5km or more [60]. None of the adolescents in this study could legally use their own independent motorised transport by the age of 15y, and yet the active transport behaviour was extremely different between Finland and Ireland. These national differences have been previously reported in the Global Matrix 2.0 PA report card, where Finland was graded 'B' and Ireland 'D' [49].

Research in active travel is limited in terms of PATs, however, there have been some initiatives to promote active travel directly or indirectly through gamification [61,62]. These programmes may start off well as the excitement of gamification kicks in, but later the novelty can wear off, reducing the potential to have sustained active travel [24]. Attrition may be avoided when designers of PATs use an established framework for functionalities in Apps [63] and follow the principles around design and usage, as outlined by Attig and Franke [17].

Other initiatives for promoting active school travel and PA in general in schools may be created by using step challenges [54]. For young adolescents, such activities need to be considered with care. There could be negative effects [64] because some students have reported they feel such challenges are impossible to win, given the head start others have on them if they started early in the morning. Alternatively, young adolescents have the feeling of guilt for not keeping up with the pace of their friends, in what Goodyear and colleagues termed, 'peer surveillance' [54].

Other innovative ways to increase active transport requires the combination of technology and the internet of things and relying upon multiple sensors, such as gyroscopes, global positioning systems (GPS) and connectivity sensors, so that students can interact more together [65]. Children took part in a design session and identified a backpack that would be lighter and track commuting with their friends so they can have more opportunities to socialise [66] is an example of going beyond the concept of PATs for the purposes of tracking PA, but also as a tool to engage with peers. The concept of wearables on bags is not a new idea, as the concepts have been considered already in the early part of the millennium [67], but it seems that commercial companies have been slow to convert this into the market.

Theoretical perspectives

Despite the differences in the levels of ownership and usage of PATs, the current study found similarities in the clusters between Finnish and Irish adolescents. One of the limitations of cluster analysis has been the data driven approach, which may lack representativeness outside of the population studied [68]. It is a recognized approach however to investigate hierarchies and commonalities among groups [69]. It is likely that the difference between the four cluster groups are a combination of readiness for behavioural change [70], as well as personal investment for self-quantification purposes [33,71]. The majority of Apps are free and can perform many of the same tasks, as what wearables can offer in terms of measuring the minimum level of PA for health, although it should be noted that the majority of the currently available PATs have been designed with the adult user in mind. Even with the latest models designed for children, the functions of PATs could be better improved to meet the needs of the young user [9]. Central to the sustainable use of PATs are the way in which feedback is given to the user. According to control theory [33], a feedback loop is introduced between the motives and the behaviour. As more wearable devices become more available, this can form part of the identity of an individual or be worn as a fashion item such as jewellery [65] which may appeal more to females. Stronger beliefs can be seen through stronger commitment to a behaviour [72]. Therefore, further research may be needed in the areas of clustering PATs ownership and usage with the role to maintain PA behaviours.

Covariates of associations

In both Finland and Ireland there is a clear association between affluence and frequency in taking part in organised sports [11,73], as demonstrated in the fully adjusted models 2 for males and females. Moreover, there was a decline in PA behaviours among the older adolescent cohort. In addition, disabilities were negatively associated with sport club membership and MVPA participation for males only. Similar findings have been reported in female populations across 15 European Countries [74], and this could relate to the already existing low levels of PA participation among females. Nonetheless, several studies have been conducted on PATs with the purpose of trying to improve the lives of people with

impairments [75-78]. Given these study findings, female user-friendly PATs may be a potentially worthwhile future area of research.

Strengths and Limitations

The data were collected through self-report surveys and reporting bias from this type of measurement tool is a common limitation to cross-sectional survey-based studies. The data were collected from national representative samples, and such inconsistencies would be typically eradicated by using larger representative samples. Although the authors attempted to harmonise their data as much as possible, not all items were the same, specifically when translated into English language. However, the cultural translation, rather than the literal translation was used in the study to make comparisons possible. This process was carried out by a researcher (first author) with competences in both languages and cultures. Other study limitations include some residual confounders may be more relevant in one country, when compared to the other, and therefore were not comparable. Although, stratification by gender and controlling for country, age, family affluence and disability were included in the adjusted models. Finally, the survey and data collection trial only gave the options for the respondents to report three main types of PATs, and as the market continues to grow, the researchers may have missed some information relating to the behaviours from other types of PATs, and time in which the individual has owned PATs. The results from this study were cross-sectional, and the length of time that the individuals had been using PATs was not reported. More understanding about the PATs use of young adolescents is needed to not only be a useful tool for promoting PA during the adolescent years, but also as part of the daily life at a later stage in adulthood.

Conclusions

The growing pervasiveness of PATs use across both Finland and Ireland is evident in the current study, and the association between PATs usage and MVPA provides very useful information for both researchers, and practitioners. Evidence from the current study highlights the positive PA behaviours for adolescents who regularly use and wear PATs, particularly with regards to males. The emergence, pervasiveness and reducing cost of wearable PATs presents opportunities for researchers to incorporate these into interventions to promote physical activity among young adolescents. Moreover, the application of evidence emerging from PA behaviour change studies could inform the design and function of future PATs. National efforts in Finland and Ireland should consider using effective dissemination strategies seeking to increase the prevalence of youth gaining access to these wearable devices, while of course acknowledging the feasibility and cost constraints in existence. Advances in technology, coupled with reductions in the cost of PATs, offer researchers a more viable opportunity to target adolescent specific PA interventions to increase the number of individuals meeting the PA guidelines.

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Conflicts of Interest

none declared

Abbreviations

CSPPA – Children's sport participation and physical activity
FAS – Family affluence scale
F-SPA – Finnish school-age physical activity
GPS – Global position systems
HRM – Heart rate monitor
MVPA – Moderate to vigorous physical activity
PA – physical activity
PATs – Physical activity trackers

Multimedia Appendix 1

Appendix Table 1. Variables that are comparable between CSPPA and F-SPA

Variable	**CSPPA**	**F-SPA**	**Coding**
Gender	Male Female Other	Male Female	Removal of 'Other'
Age	Age by Year	Age calculated by month and year of birth and calculation of age,	Grouped into 11, 13, 15y
Family Affluence Scale	FAS2	FAS3	Relative FAS
PA trackers	Apps Sports watch HRM Pedometer Other, Use Yes/No	Frequency of use in the past week	converted pedometer and other data to 'none'. Apps, SW and HRM into

	Frequency of use in past week		'none', owner' and 'user'.
Functional Difficulties	CFM	CFM	Grouped into with and without disabilities based on at least one FD with a lot of difficulties
MVPA	Two items (past 7 days) and (average 7 days), Cut off from average of two variables (rounded up	Single past 7 days	0-6 days 7 days
Organised sports	Are you currently participating in a club that is organised for a purpose of doing one particular sport or activity (exclude youth club, which may sometimes offer a number of sports) Yes No	Are you involved in sports club Yes competing Yes, not competing No, but used too No and never have	Dichotomised into members and non-members
Active Transport	Distance from school Mode from school Walking Bicycling Bus Lift by parents	Distance from school Mode from school Walking Bicycling Bus Lift by parents	Only those who reported to live within 5km. Active walkers and cyclists. Not active were motor transport

References

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