BMJ Open

Social, biological, behavioural and psychological factors and physical activity during pregnancy: a cross-sectional study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-025003
Article Type:	Research
Date Submitted by the Author:	25-Jun-2018
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Keywords:	PUBLIC HEALTH, Pregnancy, Physical activity, Exercise

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ABSTRACT

Objectives: To identify the social, biological, behavioural and psychological factors related to physical activity (PA) in early pregnancy.

Design: Secondary analysis of data from a prospective cohort study.

Setting: Cork, Ireland

Participants: Nulliparous women with singleton pregnancies were recruited and then interviewed at 15±1 weeks' gestation.

Primary and secondary outcomes: The bio-psychosocial model identified factors including: social (age), biological (body mass index), behavioural (diet) and psychological (anxiety) at 15±1 weeks' gestation. PA subgroups were identified based on a latent class analysis of their responses to a set of questions about the amount and intensity of activity they were engaging in during the pregnancy. Associations were estimated with multivariable multinomial logistic regression models.

Results: From a total of 2579, 1774 (69%) women were recruited; ages ranged from 17-45 years. PA subgroups identified: *low* PA (n = 393); *moderate* PA (n = 960); and *high* PA (n = 413). The fully adjusted model suggests, Caucasian, non-smokers, and consumers of fruit and veg were associated with high PA (vs. low). Having >12 years of schooling and a higher socioeconomic status (≥24) was related to moderate PA (vs. low).

Conclusion: The findings highlight some key un-modifiable links that should guide the development of interventions, using a population approach, in order to encourage pregnant women to engage in PA.

Key Words: Physical Activity, Exercise, Pregnancy

Word count: 3957

Strengths and limitations

- Multivariable multinomial logistic regression models were used to describe the social, biological, behaviour and psychological factors linked with physical activity levels in pregnancy within an Irish context.
- Maternal lifestyle factors were based on self-report and therefore subject to error.
- Latent class analysis was used to identify mutually exclusive subgroups in order to create a physical activity outcome measure that best describes the observed set of responses.

Funding

This work was supported by Health Research Board Ireland, (CSA/2007/2). LCK and ASK are supported by a Science Foundation Ireland Program Grant for INFANT (12/RC/2272). CF is funded by the Health Research Board SPHeRE/2013/1.

Competing interests

The authors declare that they have no competing interests.

Author's contributions

CF, ASK and SMH worked on the SCOPE data approval form. CF selected appropriate SCOPE variables from the SCOPE codebook. DD conducted the latent class analysis. CF cleaned and coded dataset and completed analysis. CF wrote the first draft of the paper. All authors contributed to successive drafts. All authors read and approved the final manuscript

Checklist STROBE checklist

Ethical approval and consent to participate

The SCOPE study was approved by the local ethics committee (Cork ECM5 (10) 05/02/08), all women provided written informed consent and the data was anonymised. For this study, research approval was obtained from the SCOPE team (RAF 3.66) and from the University College Cork, Office of Technology Transfer RU/2015/203.

Data statement

All data generated or analysed during the current study is available from the SCOPE team on reasonable request.

INTRODUCTION

The World Health Organisation defines physical activity as 'any bodily movement produced by skeletal muscles that requires energy expenditure' including leisure time physical activity, walking, household chores, games, sports or planned exercise, in the context of daily, family, and community activities[1]. Regular physical activity during pregnancy is beneficial for both mother and fetus as it helps to prevent complications, limit weight gain, and decrease the risk of gestational diabetes; while fetal benefits include decreased fat mass and improved stress tolerance[2]. Despite the significant health benefits, physical activity is lower among pregnant woman than non-pregnant women[3, 4].

Healthy women with uncomplicated pregnancies are currently advised to continue pre-pregnancy exercise activities, or begin a program of regular activity[5, 6]. The American Congress of Obstetricians and Gynaecologists (ACOG) recommend, in the absence of either medical or obstetric conditions, 30 minutes or more of daily moderate physical activity during pregnancy[7, 8]. Recommendations based on UK guidelines state that 150 minutes of moderate physical activity spread throughout the week is appropriate for pregnant women[9]. Studies using self-report measures of physical activity in the UK and USA estimate that only 3–15% of pregnant women meet current guidelines, compared to 24–26% of non-pregnant women[10, 11]. In Ireland, only one-fifth of pregnant women meet physical activity guidelines, and over 10% of pregnant women report no physical activity[4].

Developing an active lifestyle throughout pregnancy can support fetal and maternal well-being and may also produce long term benefits[2]. Physical inactivity throughout pregnancy is a major challenge and there is a need for effective strategies to increase activity during pregnancy. Recognising and understanding the correlates of physical activity, as well explaining how these correlates influence subsequent behaviour is fundamental to intervention development and implementation.

Previous observational studies have found that demographic factors such as age, income and education are important correlates of participation in physical activity during pregnancy[12-14]. Furthermore, factors such as body mass index (BMI) has been associated with both increased and decreased level of exercise during pregnancy compared to pre-pregnancy levels[12]. Of women who engaged in a regular exercise regime, those most likely to quit by the 3rd trimester were women who had a high BMI and those who had gain more weight during pregnancy[12]. Social factors like

unemployment have been shown to influence physical activity levels[15, 16] with higher education, a higher income and not having children being predictors of high exercise participation[14]. These studies have used various physical activity measures such as recreational activity, occupation or household activity as opposed to total physical activity. Therefore, a further understanding of physical activity level is essential in order to increase activity during pregnancy.

Using data from a prospective Irish cohort, this cross-sectional study aims to identify the different social, biological, behavioural and psychological factors that are linked with physical activity levels during pregnancy.

METHODS

Study Design and population

Secondary analysis of the Irish data from the prospective cohort study Screening for Pregnancy End Points (SCOPE). Scope is multicentre cohort study (Cork, Auckland, Adelaide, London, Leeds, and Manchester) with the main aim of developing screening tests to predict pre-eclampsia, small for gestational age infants and spontaneous pre-term birth as previously described[17-19]. In brief, healthy nulliparous women with singleton pregnancies were recruited and then interviewed at 15±1 weeks' gestation from Cork University Maternity Hospital (CUMH), Ireland (n=1774) between March 2008 and February 2011 with the last baby born in August 2011. At 15±1 and 20± weeks' gestation comprehensive data were collected on social factors including age, marital status, ethnicity, accommodation, socioeconomic index; behavioural and psychological factors before conception and during pregnancy. Women were followed prospectively and research midwives collected data on pregnancy outcomes and measurements of the baby. For the purpose of this cross sectional study, only data collected at 15± is analysed. The STROBE checklist was used to inform reporting of the findings (Supplementary file 1).

Outcome measure

In three separate questions, participants were asked how often they engaged in vigorous exercise *(exercise which made you breathe harder or pant)*, moderate exercise *(exercise which did not make you breathe harder or pant)*, and recreational walking *(walking for recreation or exercise)*. Responses to each of the three questions were self-reported and coded as *never; once a week; 2-3 times a week; 4-6 times a week; daily; more than twice daily*. To create a physical activity level outcome the total number of cells from a cross-tabulation would be large and difficult to collapse into groups. Therefore, latent class analysis was used to identify mutually exclusive subgroups in the sample of

participants based on these three categorical survey items[20]. The central challenge to any latent class model is to select the appropriate number of classes (or subgroups) that best describe the observed set of responses. Because the number of latent class must be set by the user, we estimated a series of models where the number of latent classes ranged from 1 to 6. The authors then met to discuss the results and a final number of latent classes were selected based on model fit statistics (using Akaike information criterion (AIC) and Bayesian information criterion (BIC)), parsimony, theoretical interpretability, and classification quality. Once the final model was chosen, participants were assigned to their most likely class (i.e. their modal assignment).

Covariates

Social measures

Characteristics included: maternal age (*years or age category; <25 year, 25-29 years, 30-34 years, ≥35years*); ethnicity (*Caucasian vs. non-Caucasian*); relationship status (*single, married/partner*); employment status (*working vs. not working*); accommodation (*own home or other*); education (*≤ 12 years of schooling vs. > 12 years of schooling*) and type of maternity care services (*Public* vs. *Private)* used. Socioeconomic index (SEI) was based on the New Zealand SEI (*<24 vs. ≥24*) with higher values reflecting greater social status[21].

Biological measures

Gravidity (*1* vs. *> 1*) was collected at 15±1 weeks' gestation. Pre-pregnancy body mass index (BMI) was calculated from pre-pregnancy weight (kg) divided by measured height squared (m2). BMI was categorised based on World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2)[22].

Psychological and behavioural measures

Based on participant reported consumption, alcohol *(no drinks; 1-2 drinks; 3-7 drinks; 8-14 drinks; >14 drinks)* was categorised as (*drinkers (≥ 1 drink) vs. non-drinkers (no drink)*); and smoking *(no smoking; 1-5 cigarettes; 6-10 cigarettes; >10 cigarettes)* was categorised as (*smokers (≥1 cigarettes) vs. non-smokers (no smoking)*). Women were asked about pre-pregnancy folic-acid supplementation *(no, yes),* and their responses *(dose)* were dichotomized as those meeting the recommended 400 µg vs. those who did not (*Yes* vs. *No*). The questionnaire administered at 15±1 weeks' gestation asked women to report the frequency with which they consumed fruit, vegetables and fish in the first 15 weeks of pregnancy. These responses were used to determine whether they were meeting the recommended five servings of fruit and veg per day (*Yes* vs. *No*), and at least 1 serving of oily fish per week (*Yes* vs. *No*).

Maternal anxiety was assessed using the short form of the State Trait Anxiety Index (STAI)[23], how much stress the woman experienced measured using the Perceived Stress Scale (PSS)[24] and depressive symptoms were assessed using the Edinburgh Postnatal Depression Scale (EPDS)[25]. Pregnancy related behaviour was measured using the behavioural response to pregnancy scale: 'all or nothing' response describes an individual who pushes oneself to keep going until they find it physically impossible; 'Limiting' response describes an individual who avoids daily activities[26]. See Supplementary file 2 for their interpretations[27].

Statistical analysis

Secondary analysis was performed using the Irish data from SCOPE in Stata (Version 13). The bio-psychosocial model was used to identify factors that are associated with PA in early pregnancy. This model recognises the influences of the biological, psychological, and social dimensions of a person's life (Figure 1)[28]. Associations between participant characteristics and the physical activity subgroups identified in the latent class analysis were explored using chi-squared test for categorical and ANOVA for continuous variables. Unadjusted multinomial logistic regression was conducted to examine the association between covariates and physical activity level. See Supplementary file 3 for the unadjusted associations. Multivariable, multinomial logistic regression was conducted using a hierarchical approach[29] whereby model 1 included the social factors, model 2 added the biological factors, and model 3 was further adjusted for the behavioural and psychological factors. All variables are included in the adjusted model. Estimated coefficients are reported as Relative Risk Ratios (RRR) with 95% confidence intervals (CI) using those who reported low physical activity as the reference category. This is because the exponentiated coefficient in multinomial logistic regression is the ratio of two relative risks (RRR) and is not to be confused or interpreted as an odds ratio (OR).

Insert Figure 1 here

RESULTS

Sample characteristics

A total of 2579 nulliparous women were invited to participate in the SCOPE Irish study, 1774 (69%) consented to take part. Ages ranged from 17 to 45 (mean age 30, standard deviation 4.5). The SCOPE Ireland women were predominantly Caucasian (n=1733, 98%), married (n=1584, 89%), with > 12 years of schooling (n=1207, 68%), and higher socioeconomic status (n=1469, 83%). The estimated

proportions of women in each BMI category were, normal (n=1058, 60%), overweight (n=495, 28%) and obese (n=221, 12%).

Physical activity levels

Physical activity data was available for 1766 women. Based on a combination of model fit, parsimony, theoretical interpretability, and classification quality, the authors agreed that a three-class model was the most appropriate one. The three physical activity subgroups thus identified were characterised as follows: *low* levels of physical activity (n = 393); *moderate* levels of physical activity (n = 960); and *high* levels of physical activity (n = 413). Based on chi-squared test and ANOVA, physical activity subgroups were crudely associated with most of the variables considered (Table 1).

Table 1: Social, biological, behavioural and psychological indicators, by physical activity subgroup

Variable		Physical Activity Subgroup (n=1766)		
	n	Low (n =393)	Moderate (n =960)	High (n= 413)
Maternal Age (years)	1774			
Mean (SD)		28.8 (5.0)	30.2 (4.3)	30.4 (4.2)
Ethnicity				
Non- Caucasian	1774	15 (36.6)	23 (56.1)	3 (7.3)
Caucasian		378 (21.9)	937 (54.3)	410 (23.8)
Marital status				
Single	1774	67 (35.6)	83 (44.2)	38 (20.2)
Married/partner		326 (20.7)	877 (55.6)	326 (20.7)
Education				
Schooling ≤12 years	1774	79 (34.5)	103 (45.0)	47 (20.5)
Schooling >12 years		314 (20.4)	857 (55.8)	366 (23.8)
Employment status				
Not working	1774	60 (31.9)	77 (41.0)	51 (27.1)
Working		333 (21.1)	883 (56.0)	362 (22.9)
Accommodation				
Other	1774	173 (28.8)	301 (50.1)	127 (21.1)
Own house		220 (18.9)	659 (56.6)	286 (24.6)
Socioeconomic index				
<24	1774	92 (30.3)	150 (49.3)	62 (20.4)
≥24		301 (20.6)	810 (55.4)	351 (24.0)
Maternity service[a]				
Private	1754	72 (16.5)	258 (59.2)	106 (24.3)
Public		317 (24.1)	696 (52.8)	305 (23.1)
BMI category[c]				
Normal	1774	241 (22.8)	556 (52.7)	258 (24.5)
Overweight		108 (21.9)	270 (54.8)	115 (23.3)
Obese		44 (20.2)	134 (61.5)	40 (23.4)
Gravidity[a]				
1 pregnancy	1754	322 (21.7)	815 (55.0)	346 (23.3)
>1 Pregnancy		67 (24.7)	139 (51.3)	65 (24.0)
Mode of delivery[b]				
C-section	1773	105 (22.3)	265 (56.1)	102 (21.6)
Vaginal birth		288 (22.3)	694 (53.7)	311 (24.1)
Smoking				
Smokers	1774	137 (28.4)	245 (50.7)	101 (20.9)
Non-smokers		256 (20.0)	715 (55.7)	312 (24.3)
Alcohol				
Drinkers	1774	292 (20.6)	778 (55.7)	335 (23.7)
Non-drinkers		101 (28.8)	172 (49.0)	78 (22.2)
Folic-acid supplement[a]				
No	1754	157 (28.0)	285 (50.9)	118 (21.1)
Yes		232 (19.4)	669 (56.0)	293 (24.5)
Five a day[a]				
No	1754	353 (23.4)	822 (54.5)	333 (22.1)
Yes		36 (14.6)	132 (53.7)	78 (31.7)
Fish[a]				
No	1754	291 (24.2)	647 (53.7)	267 (22.2)
Yes		98 (17.9)	307 (55.9)	144 (26.2)
Anxiety Index	1774	33 (27-43)	33 (27-40)	30 (23-40)
Perceived Stress Scale	1774	14 (9-19)	13 (9-18)	13 (8-17)
Depression Scale	1774	6 (3-10)	6 (3-19)	5 (2-9)
Limiting response	1774	9 (5-12)	8 (6-10)	6 (3-9)
All or nothing response	1774	7 (4-11)	8 (5-11)	8 (5-11)

Data are means (SD) number (%) and median (interquartile range). P-values are for comparisons between the three physical activity levels using analysis of variance (ANOVA), Kruskal-Wallis H or the Chi-square test.

[a]Missing values; [b]Recoded at birth; [c]BMI category defined as World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2)

Multivariable logistic regression findings

In the unadjusted multinomial logistic regression, the majority of social and behavioural factors where linked to either the moderate or high physical activity subgroups or both (See Supplementary file 2). Therefore, all variables were included in the final model. Table 2 presents the findings of the multivariable logistic regression analyses with low physical activity as the reference category.

Social, biological, behavioural and psychological

Results from the fully adjusted model (Table 2) suggest, social factors such as women aged 30-34 (RRR 2.27 [95% CI: 1.23-4.22]) and Caucasian (RRR 4.31 [95% CI: 1.14-16.26]) were associated with high physical activity (vs. low). Similarly, having > 12 years of schooling (RRR 1.55 [95% CI: 1.06-2.26]) and a higher socioeconomic status (≥24) (RRR 1.46 [95% CI: 1.05-2.05]) remained associated with moderate physical activity (vs. low).

Accounting for social and biological factors, women who consumed five portions of fruit and veg a day (RRR 1.90 [95% CI: 1.22-2.96]) and oily fish (RRR 1.47 [95% CI: 1.07-2.03]) where more likely to be in the high physical activity subgroup (vs. low), relative to those who did not consume fruit and veg or oily fish. Non-smokers were 1.45 times more likely to be in the high physical activity subgroup (vs. the low) relative to those who reported smoking (RRR 1.45 [95% CI: 1.02-2.07]). For women who did not consume alcohol relative to those who drank, the relative risk for moderate physical activity group (vs. the low) would be expected to decrease by a factor of 0.62 (RRR 0.62 [95% CI: 0.45-0.84]).

For psychological factors, the relative risk for moderate physical activity group (vs. the low), for those who reported avoiding exercise as a response to pregnancy would be expected to increase by a factor of 1.03 (RRR 1.03 [95% CI: 1.00-1.01]) and the relative risk for high physical activity group (vs. the low) would be expected to decrease by a factor of 0.85 (RRR 0.85 [95% CI: 0.81-0.88]) (vs. the low). In addition, those who reported pushing oneself as a response to pregnancy were 1.04 times more likely to be in the high physical activity subgroup (RRR 1.04 [95% CI: 1.01-1.08]) (vs. the low). Of the biological factors, the relative risk for obese women (BMI >30kg/m^2) would be expected to increase (RRR 1.49 [95% CI: 1.00-2.22]) relative to normal (BMI <24 kg/m2) (vs. the low).

Table 2: Hierarchical multinomial logistic regression

Variable	Model 1*		Model 2*		Model 3*	
	Moderate[a] (n =960)	High[a] (n= 413)	Moderate[a] (n =960)	High[a] (n= 413)	Moderate[a] (n =960)	High[a] (n= 413)
Age category						
<25 years	1[c]	1	1	1	1	1
25-29 years	1.56 (1.00-2.45)	1.69 (0.96-2.98)	1.55 (0.98-2.44)	1.71 (0.97-3.01)	1.53 (0.96-2.44)	1.69 (0.94-3.06)
30-34 years	1.55 (0.96-2.50)	2.31 (1.28-4.16)	1.55 (0.96-2.51)	2.33 (1.30-4.19)	1.49 (0.91-2.45)	2.27 (1.23-4.22)
≥ 35 years	1.48 (0.85-2.56)	1.96 (1.01-3.81)	1.48 (0.85-2.57)	2.00 (1.02-3.91)	1.42 (0.80-2.51)	1.98 (0.97-4.01)
Ethnicity						
Non- Caucasian	1	1	1	1	1	1
Caucasian	1.12 (0.54-2.32)	4.23 (1.16-15.44)	1.12 (0.54-2.32)	4.29 (1.18-15.68)	1.01 (0.47-2.16)	4.31 (1.14-16.26)
Marital status						
Single	1	1	1	1	1	1
Married/partner	1.35 (0.87-2.11)	1.31 (0.76-2.25)	1.37 (0.88-2.14)	1.32 (0.76-2.27)	1.25 (0.79-1.98)	1.06 (0.59-1.88)
Education						
Schooling ≤12 years	1	1	1	1	1	1
Schooling >12 years	1.73 (1.20-2.50)	1.49 (0.96-2.30)	1.65 (1.14-2.39)	1.48 (0.95-2.30)	1.55 (1.06-2.26)	1.35 (0.85-2.14)
Employment status						
Not working	1	1	1	1	1	1
Working	1.44 (0.95-2.18)	0.78 (0.49-1.26)	1.48 (0.98-2.26)	0.78 (0.48-1.25)	1.40 (0.92-2.14)	0.66 (0.40-1.08)
Accommodation						
Other	1	1	1	1	1	1
Own house	1.02 (0.75-1.40)	1.06 (0.73-1.53)	1.02 (0.75-1.40)	1.05 (0.73-1.53)	0.99 (0.71-1.37)	1.01 (0.68-1.48)
Socioeconomic						
<24	1	1	1	1	1	1
≥24	1.40 (1.01-1.93)	1.38 (0.93-2.03)	1.44 (1.04-2.01)	1.36 (0.92-2.01)	1.46 (1.05-2.05)	1.47 (0.98-2.21)
Maternity service[b]						
Private	1	1	1	1	1	1
Public	0.82 (0.60-1.12)	0.90 (0.63-1.30)	0.80 (0.58-1.10)	0.91 (0.63-1.30)	0.80 (0.58-1.10)	0.93 (0.64-1.36)
BMI category[d]						
Normal	-	-	1	1	1	1
Overweight			1.09 (0.83-1.44)	0.97 (0.71-1.35)	1.23 (0.85-1.50)	1.04 (0.74-1.45)
Obese			1.45 (0.98-2.15)	0.91 (0.56-1.46)	1.49 (1.00-2.22)	0.96 (0.59-1.57)
Gravidity[b]						
1 pregnancy	-	-	1	1	1	1

>1 Pregnancy			0.79 (0.57-1.10)	0.88 (0.56-1.46)	0.87 (0.62-1.22)	1.06 (0.71-1.58)
Smoking						
Smokers	-	-	-	-	1	1
Non-smokers					1.34 (1.00-1.80)	1.45 (1.02-2.07)
Alcohol						
Drinkers	-	-	-	-	1	1
Non-drinkers					0.62 (0.45-0.84)	0.75 (0.52-1.08)
Folic-acid[b]						
No	-	-	-	-	1	1
Yes					1.06 (0.78-1.46)	1.17 (0.80-1.70)
Five a day[b]						
No	-	-	-	-	1	1
Yes					1.41 (0.94-2.11)	1.90 (1.22-2.96)
Fish[b]						
No	-	-	-	-	1	1
Yes					1.35 (1.03-1.79)	1.47 (1.07-2.03)
Anxiety Index	-	-	-	-	1.01 (1.00-1.01)	1.00 (1.01-1.01)
Stress	-	-	-	-	1.02 (1.01-1.05)	1.01 (0.96-1.04)
Depression Scale	-	-	-	-	1.01 (1.00-1.04)	1.00 (1.01-1.06)
Limiting	-	-	-	-	1.03 (1.00-1.01)	0.85 (0.81-0.88)
All or nothing	-	-	-	-	1.02 (1.01-1.05)	1.04 (1.01-1.08)

*RRR (95%, CI) *P*

Includes only variables collected at 15±1 weeks' gestation (mode of delivery excluded)

[a]Reference category: low physical activity level; [b]Missing values; [c]1 denotes reference category; [d]BMI category defined as World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2)

DISCUSSION

Women aged 30-34 years had increased probability of being in the high physical activity subgroup (vs. the low) relative to women <25 years of age. Women with a higher educational level, in a higher social class and in the obese BMI category (>30kg/m^2) had increased probability of being in the moderate physical activity subgroup (vs. the low). Non-smokers were more likely to be in the high physical activity relative to smoker and women who consumed the recommended five servings of fruit and veg per day and at least 1 serving of oily fish per week were more likely to be in the high physical activity subgroup.

Women aged 30-34 years had increased probability of being in the high physical activity subgroup (vs. the low). This is noteworthy given that other studies have reported higher levels of physical activity among younger age groups[13]. Consistent with previous studies on physical activity, pregnant women with a higher educational level and in a higher social class were more likely to engage in moderate levels of physical activity[13, 30, 31]. Similar to other studies, factors associated with exercise during pregnancy include income level, no other children at home, white ethnicity and activity prior to pregnancy [14]. Women with a high education may have access to more information, may be aware of the recommended guidelines and have more time for physical activity during pregnancy[30, 32]. From a public health perspective, a key concern is social inequalities in physical activity, as physical activity participation varies by socioeconomic status, favouring those in a higher social class[33]. Women that don't achieve a high level of education and are of a lower social class are less active and should be the focus of intervention efforts. A previous study showed that women with high pre-pregnancy BMI were less active than women with a low pregnancy BMI[30]. By contrast, the present study showed that pregnant women in the obese BMI category (BMI >30kg/m^2) had increased probability of being in the moderate physical activity subgroup (vs. the low). The relationship between BMI and physical activity observed in this and in other studies is complex. Obese women may be more likely to engage in less strenuous activity or these women may have over-reported their moderate physical activity levels due to the unclear descriptions of physical activity in the survey questions. Moreover, it could reflect perceived exertion where heavier women find themselves performing activity for which they feel like they are exerting themselves, relative to lighter women. Previous interventions for improving physical activity for pregnant women have focused on high risk groups such as obese women[34]. Non-smokers were more likely to be in the high physical activity subgroup relative to smokers, which is consistent with other studies[31, 35]. Furthermore, women who consumed the recommended five servings of fruit and veg per day and at least 1 serving of oily fish per week were more likely to be in the high physical activity subgroup

which indicates some awareness around healthy lifestyle behaviours during pregnancy. Dolan and Galizzi 2015, state that no behaviour sits in a vacuum, and one healthy behaviour can greatly affect another[36]. Furthermore, exercise and fruit and veg consumption have been identified as being in the same behavioural cluster [37] and perhaps explains a potential spill over effect to physical activity as women are already engaging in a number of healthy behaviours. Women who drank alcohol during pregnancy were more likely to be in the moderate physical activity subgroup. This coexistence of healthy and unhealthy behaviours was also identified in other studies[38]. Similar results were found in an Irish sample of adults aged 18 years and over, where the majority of moderate drinkers reported high levels of physical activity[39].

This analysis uses data from one of the largest studies of pregnant women (SCOPE). Furthermore, the population-based nature of the study allowed the estimation of the associations of a variety of social, biological, behavioural and psychological factors in a more representative sample than is often possible. Future research should find and use a better measure of physical activity to accurately assess physical activity levels and investigate the frequency, duration and intensity. While demographic correlates of physical activity are informative, they are largely un-modifiable. However, increased understanding of these correlates can be used to guide the development of interventions and to identify those who need the intervention, in this case, women of different cultural backgrounds, low educational attainment and lower socioeconomic backgrounds.

Limitations of this study

This work is secondary analysis of data collected with an observational study design. Inherent to the nature of the secondary analysis, the available data was not collected to address this particular research question. Furthermore, most of the data on maternal lifestyle factors were based on self-report and is susceptible to biased reporting of the lifestyle behaviours and physical activity. Lifestyle factors in the SCOPE study were based on a range of questions from a non-validated questionnaire which should be acknowledged in order to interpret our results. Original survey questions on physical activity including vigorous exercise, moderate exercise and recreational walking used descriptions such as breathing and panting. Social desirability bias may have thus led to women over-reporting their physical activity levels. Although self-report has capacity to over or underestimate true physical activity level, the use of daily exercise leading to heavy breathing or being out of breath has been used in other studies[40]. In order to create a more robust indicator for this study, latent class analysis was conducted to classify pregnant women's physical activity subgroup based on multiple survey questions. The resulting classification should then be less prone

to error than classifying participants based on any single question, but given that there is no gold-standard to compare to, we must still rely on our subjective interpretation of the classification. Furthermore, the data from this cross-sectional study does not illustrate exercise conditions throughout pregnancy or the variation in exercise that may occur from trimester to trimester. Previous research advocates for the continuation of pre-pregnancy and early pregnancy physical activity levels into later pregnancy [41]. Therefore, longitudinal follow up is warranted in future studies.

CONCLUSION

This study identifies the links between social, biological, behavioural and psychological factors and physical activity level during pregnancy in a healthy pregnant population. The findings highlight some key potential links including those of a young maternal age, those with a low education level and those from a low socioeconomic background and physical activity. It also highlights potential behavioural clusters and spill over effects to physical activity. These factors should be considered for future interventions to improve physical activity levels during pregnancy.

List of abbreviations

SCOPE, Screening for Pregnancy End Points; RRR, Relative Risk Ratio; ACOG, American Congress of Obstetricians and Gynaecologists; BMI, body mass index; UK, United Kingdom; USA, United States of America; CUMH, Cork University Maternity Hospital; STROBE, strengthening the reporting of observational studies in epidemiology; AIC, Akaike information criterion; BIC, Bayesian information criterion; SEI, Socioeconomic index; STAI, State Trait Anxiety Index; PSS, Perceived Stress Scale; EPDS, Edinburgh Postnatal Depression Scale

Supplementary data

File 1: STROBE statement

File 2: Psychological well-being and their interpretations

File 3: Unadjusted associations between social, biological, behavioural and psychological indicators and moderate or high levels of physical activity levels in pregnancy

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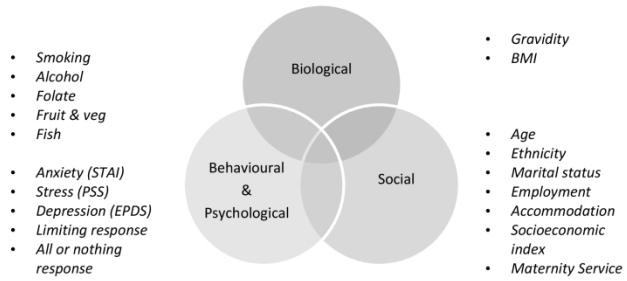
evaluating the longitudinal impact using neurological and nutritional endpoints (BASELINE) birth cohort (Cork, Ireland). *BMJ Open* 2017;7(11) doi: 10.1136/bmjopen-2017-017987

Figure 1: Biopsychosocial model for physical activity using data from the Irish cohort of SCOPE



209x297mm (300 x 300 DPI)

STROBE (Strengthening The Reporting of OBservational Studies in Epidemiology) Checklist

A checklist of items that should be included in reports of observational studies. You must report the page number in your manuscript where you consider each of the items listed in this checklist. If you have not included this information, either revise your manuscript accordingly before submitting or note N/A.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Section and Item	Item No.	Recommendation	Reported on Page No.
Title and Abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/Rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			
Study Design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	N/A
		Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	N/A
		Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants	5-7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed	N/A
		Case-control study—For matched studies, give matching criteria and the number of controls per case	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7

Section and Item	Item No.	Recommendation	Reported on Page No.
Data Sources/ Measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-7
Bias	9	Describe any efforts to address potential sources of bias	N/A
Study Size	10	Explain how the study size was arrived at	7
Quantitative Variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-7
Statistical Methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-12
		(*b*) Describe any methods used to examine subgroups and interactions	7-12
		(*c*) Explain how missing data were addressed	Table 1
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	N/A N/A 7-12
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Table 1
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive Data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-12, Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome Data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	N/A
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	7-12

Section and Item	Item No.	Recommendation	Reported on Page No.
Main Results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-12
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other Analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key Results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	12-15
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Once you have completed this checklist, please save a copy and upload it as part of your submission. DO NOT include this checklist as part of the main manuscript document. It must be uploaded as a separate file.

Supplementary file 2: Psychological well-being and their interpretations; adapted from McCarthy et al[27]

Psychological and behavioural scales	Score range and interpretation
Short form of the State Trait Anxiety Index (STAI)[24]	Short –form STAI scores 6-24 converted to a score range of 20-80 to mimic the full version of the STAI, with high scores indicating high state anxiety (i.e. current anxiety)
Perceived Stress Scale (PSS)[25]	0-40, with high scores representing high scores representing higher perceived stress (feelings of lack of control)
Edinburgh Postnatal Depression Scale (EPDS)[26]	As a continuous measure (0-30) where a higher score indicates a higher probability of depression
Behavioural response to pregnancy scale[27]	Two subscales: 1. Limiting/resting behaviour (0-20)[a] **2.** All-or-nothing behaviour (0-28)[b]

[a]***Limiting response includes:*** *avoiding exercise, life on hold, avoiding usual activities, going to bed during the day, not being able to do usual level of activities.*

[b]***All-or-nothing response includes:*** *overdoing and needing to rest, pushing oneself, carrying on as normal, doing too much.*

Supplementary file 3: Unadjusted associations for moderate or high levels of physical activity levels

Variable	Physical Activity Subgroups			
	Moderate[a] (n =960)		High[a] (n= 413)	
Age category				
<25 years	1[d]		1	
25-29 years	2.35 (1.63-3.41)	0.000	2.02 (1.26-3.22)	<0.0001
30-34 years	2.70 (1.89-3.85)	0.000	3.07 (1.97-4.78)	<0.0001
≥ 35 years	2.48 (1.58-3.89)	0.000	2.62 (1.52-4.54)	<0.0001
Ethnicity				
Non-Caucasian	1		1	
Caucasian	1.62 (0.84-3.13)	0.155	5.42 (1.56-18.88)	<0.0001
Marital status				
Single	1		1	
Married/partner	2.17 (1.54-3.07)	0.000	2.03 (1.54-3.07)	<0.0001
Education				
Schooling ≤12 years	1		1	
Schooling >12 years	2.09 (1.52-2.88)	0.000	1.96 (1.32-2.90)	<0.0001
Employment status				
Not working	1		1	
Working	2.07 (1.44-2.96)	0.000	1.28 (0.86-1.91)	0.230
Accommodation				
Other	1		1	
Own house	1.72 (1.35-2.19)	0.000	1.77 (1.35-2.36)	<0.0001
Socioeconomic index				
<24	1		1	
≥24	1.65 (1.23-2.21)	0.001	1.73 (1.21-2.47)	<0.0001
Maternity service[b]				
Private	1		1	
Public	0.61 (0.46-0.82)	0.001	0.65 (0.47-0.92)	<0.0001
BMI category[e]				
Normal	1		1	
Overweight	1.08 (0.83-1.42)	0.559	0.99 (0.73-1.36)	0.973
Gravidity[b]				
1 pregnancy	1		1	
>1 Pregnancy	0.82 (0.60-1.13)	0.221	0.90 (0.62-1.31)	0.592
Mode of delivery[c]				
C-section	1		1	
Vaginal birth	0.95 (0.73-1.24)	0.732	1.11 (0.81-1.52)	0.512
Smoking				
Smoker	1		1	
Non-smoker	1.56 (1.21-2.01)	0.001	1.65 (1.22-2.24)	<0.0001
Alcohol				
Drinker	1		1	
Non-drinker	0.63 (0.48-0.83)	0.001	0.67 (0.48-0.94)	<0.0001
Folic-acid supplement[b]				
No	1		1	
Yes	1.59 (1.24-2.03)	0.000	1.68 (1.25-2.26)	<0.0001
Five a day[b]				
No	1		1	
Yes	1.57 (1.07-2.32)	0.022	2.30 (1.51-3.50)	<0.0001
Fish[b]				
No	1		1	
Yes	1.41 (1.08-1.84)	0.012	1.60 (1.18-2.17)	<0.0001
Anxiety Index	0.99 (0.98-1.00)	0.003	0.99 (0.98-1.00)	<0.0001
Perceived Stress Scale	0.98 (0.97-1.00)	0.084	0.97 (0.95-1.00)	<0.0001
Depression Scale	0.96 (0.94-0.99)	0.003	0.94 (0.95-0.97)	<0.0001
Limiting response	0.94 (0.91-0.96)	0.000	0.86 (0.83-0.89)	<0.0001
All or nothing response	1.02 (1.00-1.04)	0.215	1.02 (0.99-1.05)	0.260

[a]Reference category: low physical activity level; [b]Missing values; [c]Recoded at birth [d]1 denotes reference category [e]BMI category World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2)

BMJ Open

Social, biological, behavioural and psychological factors related to physical activity during early pregnancy in the Screening for Pregnancy Endpoints (Cork, Ireland) cohort study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-025003.R1
Article Type:	Research
Date Submitted by the Author:	18-Feb-2019
Complete List of Authors:	Flannery, Caragh; National University of Ireland, Galway , Health Behaviour Change Research Group, School of Psychology ; University College Cork , School of Public Health Dahly, Darren; University College Cork, School of Public Health ; University College Cork , Health Research Board, Clinical Research Facility Cork Byrne, Molly; National University of Ireland, Galway , Health Behaviour Change Research Group, School of Psychology Khashan, Ali; University College Cork, School of Public Health; University College Cork , The Irish Centre for Fetal and Neonatal Translational Research (INFANT) Mc Hugh, Sheena; University College Cork, School of Public Health Kenny, Louise; University of Liverpool School of Life Sciences, Department of Women's and Children's Health McAuliffe, Fionnuala; University College Dublin, UCD Perinatal Research Centre, School of Medicine; University College Dublin, National Maternity Hospital Kearney, Patricia; University College Cork, School of Public Health
Primary Subject Heading:	Public health
Secondary Subject Heading:	Obstetrics and gynaecology, Epidemiology
Keywords:	PUBLIC HEALTH, Pregnancy, Physical activity, Exercise

Title: 'Social, biological, behavioural and psychological factors related to physical activity during early pregnancy in the Screening for Pregnancy Endpoints (Cork, Ireland) cohort study'

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ABSTRACT

Objectives: To identify the social, biological, behavioural and psychological factors related to physical activity (PA) in early pregnancy.

Design: Secondary analysis of data from a prospective cohort study.

Setting: Cork, Ireland

Participants: Nulliparous women with singleton pregnancies were recruited and then interviewed at 15±1 weeks' gestation.

Primary and secondary outcomes: The bio-psychosocial model identified factors including: social (age), biological (body mass index), behavioural (diet) and psychological (anxiety) at 15±1 weeks' gestation. PA subgroups were identified based on a latent class analysis of their responses to a set of questions about the amount and intensity of activity they were engaging in during the pregnancy. Associations were estimated with multivariable multinomial logistic regression models.

Results: From a total of 2579, 1774 (69%) women were recruited; ages ranged from 17-45 years. Based on a combination of model fit, theoretical interpretability, and classification quality, the latent class analyses identified three PA subgroups: *low* PA (n = 393); *moderate* PA (n = 960); and *high* PA (n = 413). The fully adjusted model suggests non-smokers, and consumers of fruit and veg were more likely to be in the high PA subgroup (vs. low). Women with more than 12 years of schooling and a higher socioeconomic status were more likely to be in the moderate PA subgroup (vs. low).

Conclusion: The findings highlight potential links between physical activity, a low education level, and a low socioeconomic background. These factors should be considered for future interventions to improve physical activity levels during pregnancy.

Key Words: Physical Activity, Exercise, Pregnancy

Word count: 3957

Strengths and limitations

- Multivariable multinomial logistic regression models were used to estimate the associations between physical activity and social, biological, behaviour and psychological factors in pregnancy within an Irish context.
- Maternal lifestyle factors were based on self-report and therefore subject to error.
- Latent class analysis was used to identify mutually exclusive subgroups in order to create a physical activity outcome measure that best describes the observed set of responses.

Funding

This work was supported by Health Research Board Ireland, (CSA/2007/2). LCK and ASK are supported by a Science Foundation Ireland Program Grant for INFANT (12/RC/2272). CF is funded by the Health Research Board SPHeRE/2013/1.

Competing interests

The authors declare that they have no competing interests.

Author's contributions

CF, ASK, DD and SMH formulated the overarching study aims and methodology. Data management was controlled by CF, who selected appropriate variables, cleaned and maintained the research data. DD conducted the latent class analysis and CF conducted the formal analysis, running the multinomial logistic regression. CF wrote the initial draft of the paper. MB, FMA, PMK and LCK contributed to successive drafts, reviewing and editing. All authors read and approved the final manuscript.

Checklist STROBE checklist

Ethical approval and consent to participate

The SCOPE study was approved by the local ethics committee (Cork ECM5 (10) 05/02/08), all women provided written informed consent and the data was anonymised. For this study, research approval was obtained from the SCOPE team (RAF 3.66) and from the University College Cork, Office of Technology Transfer RU/2015/203.

Data statement

All data generated or analysed during the current study is available from the SCOPE team on reasonable request.

INTRODUCTION

Physical activity is defined as 'any bodily movement produced by skeletal muscles that requires energy expenditure' including leisure time physical activity, walking, household chores, games, sports or planned exercise, in the context of daily, family, and community activities[1]. National and international guidelines for pregnancy recommend 30 minutes or more of daily moderate physical activity, or 150 minutes of moderate physical activity spread throughout the week [2-6]. Regular physical activity during pregnancy is beneficial for both mother and fetus, as it helps to prevent complications, limit weight gain, and decrease the risk of gestational diabetes[7]. Despite these significant health benefits, physical activity is lower among pregnant women [8, 9]. Studies using self-report measures of physical activity in the UK and USA estimate that only 3–15% of pregnant women meet current guidelines, compared to 24–26% of non-pregnant women[10, 11]. In Ireland, only one-fifth of pregnant women meet physical activity guidelines, and over 10% of pregnant women report no physical activity[9].

Consequently, there is a need for effective strategies to increase activity during pregnancy. Recognising and understanding the correlates of physical activity, as well explaining how these correlates may influence subsequent behaviour, is fundamental to intervention development and implementation.

Previous observational studies have found that demographic factors such as age, income and education are important correlates of participation in physical activity during pregnancy [12-14]. Furthermore, factors such as body mass index (BMI) has been associated with both increased and decreased level of exercise during pregnancy compared to pre-pregnancy levels[12]. Of women who engaged in a regular exercise regime, those most likely to quit by the 3rd trimester were women who had a high BMI and those who had gained more weight during pregnancy[12]. Social factors like unemployment have been shown to influence physical activity levels[15, 16] with higher education, a higher income and not having children being predictors of high exercise participation[14]. These studies have used various physical activity measures such as recreational activity, occupation or household activity as opposed to total physical activity. Therefore, a further understanding of physical activity level is essential in order to increase activity during pregnancy.

Using data from a prospective Irish cohort, this study aims to identify the different social, biological, behavioural and psychological factors that are linked with physical activity levels during pregnancy.

METHODS

Study Design and population

Secondary analysis of the Irish data from the prospective cohort study Screening for Pregnancy End Points (SCOPE). Scope is multicentre cohort study (Cork, Auckland, Adelaide, London, Leeds, and Manchester) with the main aim of developing screening tests to predict pre-eclampsia, small for gestational age infants and spontaneous pre-term birth as previously described[17-19]. In brief, healthy nulliparous women with singleton pregnancies were recruited and then interviewed at 15±1 weeks' gestation from Cork University Maternity Hospital (CUMH), Ireland (n=1774) between March 2008 and February 2011 with the last baby born in August 2011. At 15±1 and 20± weeks' gestation comprehensive data were collected on social factors including age, marital status, ethnicity, accommodation, socioeconomic index; behavioural and psychological factors before conception and during pregnancy. Women were followed prospectively and research midwives collected data on pregnancy outcomes and measurements of the baby. For the purpose of this study, only data collected at 15± is analysed. The STROBE checklist for cohort studies was used to inform reporting of the findings (Supplementary file 1).

Patient and Public Involvement

This is secondary analysis using data from the SCOPE study. Pregnant women were not directly involved in the design or administration of this analysis.

Outcome measure

In three separate questions, participants were asked how often they engaged in vigorous exercise *(exercise which made you breathe harder or pant)*, moderate exercise *(exercise which did not make you breathe harder or pant)*, and recreational walking *(walking for recreation or exercise)*. Responses to each of the three questions were self-reported and coded as *never; once a week; 2-3 times a week; 4-6 times a week; daily; more than twice daily*. Latent class analysis was used to identify mutually exclusive subgroups in the sample of participants based on these three categorical survey items[20]. The central challenge to any latent class model is to select the appropriate number of classes (or subgroups) that best describe the observed set of responses. Because the number of latent class must be set by the user, we estimated a series of models where the number of latent classes ranged from 1 to 6. The authors then met to discuss the results and a final number of latent classes were selected based on model fit statistics (using Akaike information criterion (AIC) and Bayesian information criterion (BIC)), parsimony, theoretical interpretability, and classification

quality. Once the final model was chosen, participants were assigned to their most likely class (i.e. their modal assignment). Latent class models were estimated using MPlus version 8.0.

Covariates

Social measures

Characteristics included: maternal age (*years or age category; <25 year, 25-29 years, 30-34 years, ≥35years*); ethnicity (*Caucasian vs. non-Caucasian*); relationship status (*single, married/partner*); employment status (*working vs. not working*); accommodation (*own home or other*); education (*≤ 12 years of schooling vs. > 12 years of schooling*) and type of maternity care services (*Public* vs. *Private)* used. Socioeconomic index (SEI) was based on an occupation-based measure of socio-economic status 'New Zealand SEI' (*<24 vs. ≥24*) with higher values reflecting greater social status[21].

Biological measures

Gravidity (*1* vs. *> 1*) was collected at 15±1 weeks' gestation. Body mass index (BMI) was calculated from pregnancy weight (kg) divided by measured height squared (m2) from the first SCOPE visit at 15±1 weeks' gestation. BMI was categorised based on World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5-24.9kg/m^2), overweight (≥25-29.9kg/m^2), obese (≥30kg/m^2)[22].

Psychological and behavioural measures

Based on participant reported consumption, alcohol measured as drinks per week at 15±1 weeks' gestation *(no drinks; 1-2 drinks; 3-7 drinks; 8-14 drinks; >14 drinks)* was categorised as (*drinkers (≥ 1 drink) vs. non-drinkers (no drink)*); and smoking per day at 15±1 weeks' gestation *(no smoking; 1-5 cigarettes; 6-10 cigarettes; >10 cigarettes)* was categorised as (*smokers (≥1 cigarettes) vs. non-smokers (no smoking)*). Women were asked about pre-pregnancy folic-acid supplementation *(no, yes),* and their responses *(dose)* were dichotomized as those meeting the recommended 400 µg vs. those who did not (*Yes* vs. *No*). The questionnaire administered at 15±1 weeks' gestation asked women to report the frequency with which they consumed fruit, vegetables and fish in the first 15 weeks of pregnancy. These responses were used to determine whether they were meeting the recommended five servings of fruit and veg per day (*Yes* vs. *No*), and at least 1 serving of oily fish per week (*Yes* vs. *No*).

Maternal anxiety was assessed using the short form of the State Trait Anxiety Index (STAI)[23], how much stress the woman experienced measured using the Perceived Stress Scale (PSS)[24] and depressive symptoms were assessed using the Edinburgh Postnatal Depression Scale (EPDS)[25].

Pregnancy related behaviour was measured using the behavioural response to pregnancy scale: 'all or nothing' response describes an individual who pushes oneself to keep going until they find it physically impossible; 'Limiting' response describes an individual who avoids daily activities[26]. See Supplementary file 2 for their interpretations[27].

Statistical analysis

Secondary analysis was performed using the Irish data from SCOPE in Stata (Version 13). The bio-psychosocial model was used to identify factors that are associated with PA in early pregnancy. This model recognises the influences of the biological, psychological, and social dimensions of a person's life (Figure 1)[28]. Associations between participant characteristics and the physical activity subgroups identified in the latent class analysis were explored using chi-squared test for categorical and ANOVA for continuous variables. Unadjusted multinomial logistic regression was conducted to examine the association between covariates and physical activity level. See Supplementary file 3 for the unadjusted associations. Multivariable, multinomial logistic regression was conducted using a hierarchical approach[29] whereby model 1 included the social factors, model 2 added the biological factors, and model 3 was further adjusted for the behavioural and psychological factors. All variables are included in the adjusted model. Estimated coefficients are reported as Relative Risk Ratios (RRR) with 95% confidence intervals (CI) using those who reported low physical activity as the reference category. This is because the exponentiated coefficient in multinomial logistic regression is the ratio of two relative risks (RRR) and should not be interpreted as an odds ratio (OR).

Insert Figure 1 here

RESULTS

Sample characteristics

A total of 2579 nulliparous women were invited to participate in the SCOPE Irish study, 1774 (69%) consented to take part (Figure 2). Ages ranged from 17 to 45 (mean age 30, standard deviation 4.5). The SCOPE Ireland women were predominantly Caucasian (n=1733, 98%), married (n=1584, 89%), with > 12 years of schooling (n=1207, 68%), and higher socioeconomic status (n=1469, 83%). The estimated proportions of women in each BMI category were, normal (n=1058, 60%), overweight (n=495, 28%) and obese (n=221, 12%).

Insert Figure 2 here

Physical activity levels

Physical activity data was available for 1766 women. Based on a combination of model fit, parsimony, theoretical interpretability, and classification quality, the authors agreed that a three-class model was the most appropriate one. The three physical activity subgroups thus identified were characterised as follows: *low* levels of physical activity (n=393); *moderate* levels of physical activity (n=960); and *high* levels of physical activity (n=413). Based on chi-squared test and ANOVA, physical activity subgroups were crudely associated with most of the variables considered (Table 1).

Table 1: Social, biological, behavioural and psychological indicators, by physical activity subgroup

Variable		Physical Activity Subgroup (n=1766)		
	n	Low (n =393)	Moderate (n =960)	High (n= 413)
Maternal Age (years)	1774			
Mean (SD)		28.8 (5.0)	30.2 (4.3)	30.4 (4.2)
Ethnicity				
Non-Caucasian	1774	15 (36.6)	23 (56.1)	3 (7.3)
Caucasian		378 (21.9)	937 (54.3)	410 (23.8)
Marital status				
Single	1774	67 (35.6)	83 (44.2)	38 (20.2)
Married/partner		326 (20.7)	877 (55.6)	326 (20.7)
Education				
Schooling ≤12 years	1774	79 (34.5)	103 (45.0)	47 (20.5)
Schooling >12 years		314 (20.4)	857 (55.8)	366 (23.8)
Employment status				
Not working	1774	60 (31.9)	77 (41.0)	51 (27.1)
Working		333 (21.1)	883 (56.0)	362 (22.9)
Accommodation				
Other	1774	173 (28.8)	301 (50.1)	127 (21.1)
Own house		220 (18.9)	659 (56.6)	286 (24.6)
Socioeconomic index				
<24	1774	92 (30.3)	150 (49.3)	62 (20.4)
≥24		301 (20.6)	810 (55.4)	351 (24.0)
Maternity service[a]				
Private	1754	72 (16.5)	258 (59.2)	106 (24.3)
Public		317 (24.1)	696 (52.8)	305 (23.1)
BMI category[c]				
Underweight	1774	5 (23.8)	11 (52.4)	5 (23.8)
Normal		236 (22.8)	545 (52.7)	253 (24.5)
Overweight		108 (21.9)	270 (54.8)	115 (23.3)
Obese		44 (20.2)	134 (61.5)	40 (18.4)
Gravidity[a]				
1 pregnancy	1754	322 (21.7)	815 (55.0)	346 (23.3)
>1 Pregnancy		67 (24.7)	139 (51.3)	65 (24.0)
Mode of delivery[b]				
C-section	1773	105 (22.3)	265 (56.1)	102 (21.6)
Vaginal birth		288 (22.3)	694 (53.7)	311 (24.1)
Smoking				
Smokers	1774	137 (28.4)	245 (50.7)	101 (20.9)
Non-smokers		256 (20.0)	715 (55.7)	312 (24.3)
Alcohol				
Drinkers	1774	292 (20.6)	778 (55.7)	335 (23.7)
Non-drinkers		101 (28.8)	172 (49.0)	78 (22.2)
Folic-acid supplement[a]				
No	1754	157 (28.0)	285 (50.9)	118 (21.1)
Yes		232 (19.4)	669 (56.0)	293 (24.5)
Five a day[a]				
No	1754	353 (23.4)	822 (54.5)	333 (22.1)
Yes		36 (14.6)	132 (53.7)	78 (31.7)

Table 1: Social, biological, behavioural and psychological indicators, by physical activity subgroup (continued)

Fish[a]				
No	1754	291 (24.2)	647 (53.7)	267 (22.2)
Yes		98 (17.9)	307 (55.9)	144 (26.2)
Anxiety Index	1774	33 (27-43)	33 (27-40)	30 (23-40)
Perceived Stress Scale	1774	14 (9-19)	13 (9-18)	13 (8-17)
Depression Scale	1774	6 (3-10)	6 (3-19)	5 (2-9)
Limiting response	1774	9 (5-12)	8 (6-10)	6 (3-9)
All or nothing response	1774	7 (4-11)	8 (5-11)	8 (5-11)

Data are means (SD) number (%) and median (interquartile range). Kruskal-Wallis H or the Chi-square test.
[a]Missing values; [b]Recoded at birth; [c]BMI category defined as World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5-24.9kg/m^2), overweight (≥25-29.9kg/m^2), obese (≥30kg/m^2)

Multivariable logistic regression findings

In the unadjusted multinomial logistic regression, the majority of social and behavioural factors where linked to either the moderate or high physical activity subgroups or both (See Supplementary file 2). Therefore, all variables were included in the final model. Table 2 presents the findings of the multivariable logistic regression analyses with low physical activity as the reference category.

Social, biological, behavioural and psychological

In model 1, social factors such as employment, accommodation and type of maternity service were not statistically significant for moderate physical activity (vs. low) or high physical activity (vs. low). Furthermore, in model 2, biological factors BMI and gravidity were not statistically significant for moderate physical activity (vs. low) or high physical activity (vs. low).

Results from the fully adjusted model (Table 2) suggest, social factors such as women aged 30-34 (RRR 2.27 [95% CI: 1.23-4.22]) were associated with high physical activity (vs. low), with non-Caucasian's being less likely to be in the high physical activity subgroup (vs. low) (RRR 0.23 [95% CI: 0.06-0.86]). Similarly, having > 12 years of schooling (RRR 1.55 [95% CI: 1.06-2.26]) and a higher socioeconomic status (≥24) (RRR 1.46 [95% CI: 1.05-2.05]) remained associated with moderate physical activity (vs. low). Of the biological factors, the relative risk for obese women (BMI >30kg/m^2) would be expected to increase (RRR 1.49 [95% CI: 1.00-2.22]) for moderate physical activity relative to normal (BMI <24 kg/m2) (vs. the low).

Accounting for social and biological factors, women who consumed five portions of fruit and veg a day (RRR 1.90 [95% CI: 1.22-2.96]) and oily fish (RRR 1.47 [95% CI: 1.07-2.03]) where more likely to be in the high physical activity subgroup (vs. low), relative to those who did not consume fruit and

veg or oily fish. Non-smokers were 1.45 times more likely to be in the high physical activity subgroup (vs. the low) relative to those who reported smoking (RRR 1.45 [95% CI: 1.02-2.07]). For women who did not consume alcohol relative to those who drank, the relative risk for moderate physical activity group (vs. the low) would be expected to decrease by a factor of 0.62 (RRR 0.62 [95% CI: 0.45-0.84]).

For psychological factors, the relative risk for moderate physical activity group (vs. the low), for those who reported avoiding exercise as a response to pregnancy would be expected to increase by a factor of 1.03 (RRR 1.03 [95% CI: 1.00-1.01]) and the relative risk for high physical activity group (vs. the low) would be expected to decrease by a factor of 0.85 (RRR 0.85 [95% CI: 0.81-0.88]) (vs. the low). In addition, those who reported pushing oneself as a response to pregnancy were 1.04 times more likely to be in the high physical activity subgroup (RRR 1.04 [95% CI: 1.01-1.08]) (vs. the low).

Table 2: Hierarchical multinomial logistic regression

Variable[a]	Model 1*		Model 2*		Model 3*	
	Moderate[b] (n =960)	High[b] (n= 413)	Moderate[b] (n =960)	High[b] (n= 413)	Moderate[b] (n =960)	High[b] (n= 413)
Age category						
<25 years	1[d]	1	1	1	1	1
25-29 years	1.56 (1.00-2.45)	1.69 (0.96-2.98)	1.55 (0.98-2.44)	1.71 (0.97-3.01)	1.53 (0.96-2.44)	1.69 (0.94-3.06)
30-34 years	1.55 (0.96-2.50)	2.31 (1.28-4.16)	1.55 (0.96-2.51)	2.33 (1.30-4.19)	1.49 (0.91-2.45)	2.27 (1.23-4.22)
≥ 35 years	1.48 (0.85-2.56)	1.96 (1.01-3.81)	1.48 (0.85-2.57)	2.00 (1.02-3.91)	1.42 (0.80-2.51)	1.98 (0.97-4.01)
Ethnicity						
Caucasian	1	1	1	1	1	1
Non-Caucasian	0.89 (0.43-1.86)	0.24 (0.06-0.86)	0.89 (0.43-1.86)	0.23 (0.063-0.85)	0.96 (0.46-2.11)	0.23 (0.06-0.86)
Marital status						
Single	1	1	1	1	1	1
Married/partner	1.35 (0.87-2.11)	1.31 (0.76-2.25)	1.37 (0.88-2.14)	1.32 (0.76-2.27)	1.25 (0.79-1.98)	1.06 (0.59-1.88)
Education						
Schooling ≤12 years	1	1	1	1	1	1
Schooling >12 years	1.73 (1.20-2.50)	1.49 (0.96-2.30)	1.65 (1.14-2.39)	1.48 (0.95-2.30)	1.55 (1.06-2.26)	1.35 (0.85-2.14)
Employment status						
Not working	1	1	1	1	1	1
Working	1.44 (0.95-2.18)	0.78 (0.49-1.26)	1.48 (0.98-2.26)	0.78 (0.48-1.25)	1.40 (0.92-2.14)	0.66 (0.40-1.08)
Accommodation						
Other	1	1	1	1	1	1
Own house	1.02 (0.75-1.40)	1.06 (0.73-1.53)	1.02 (0.75-1.40)	1.05 (0.73-1.53)	0.99 (0.71-1.37)	1.01 (0.68-1.48)
Socioeconomic						
<24	1	1	1	1	1	1
≥24	1.40 (1.01-1.93)	1.38 (0.93-2.03)	1.44 (1.04-2.01)	1.36 (0.92-2.01)	1.46 (1.05-2.05)	1.47 (0.98-2.21)
Maternity service[c]						
Private	1	1	1	1	1	1
Public	0.82 (0.60-1.12)	0.90 (0.63-1.30)	0.80 (0.58-1.10)	0.91 (0.63-1.30)	0.80 (0.58-1.10)	0.93 (0.64-1.36)
BMI category [e]						
Underweight/Normal	-	-	1	1	1	1
Overweight			1.09 (0.83-1.44)	0.97 (0.71-1.35)	1.23 (0.85-1.50)	1.04 (0.74-1.45)
Obese			1.45 (0.98-2.15)	0.91 (0.56-1.46)	1.49 (1.00-2.22)	0.96 (0.59-1.57)
Gravidity[c]						
1 pregnancy	-	-	1	1	1	1

>1 Pregnancy			0.79 (0.57-1.10)	0.88 (0.56-1.46)	0.87 (0.62-1.22)	1.06 (0.71-1.58)
Smoking						
Smokers	-	-	-	-	1	1
Non-smokers					1.34 (1.00-1.80)	1.45 (1.02-2.07)
Alcohol						
Drinkers	-	-	-	-	1	1
Non-drinkers					0.62 (0.45-0.84)	0.75 (0.52-1.08)
Folic-acid[c]						
No	-	-	-	-	1	1
Yes					1.06 (0.78-1.46)	1.17 (0.80-1.70)
Five a day[c]						
No	-	-	-	-	1	1
Yes					1.41 (0.94-2.11)	1.90 (1.22-2.96)
Fish[c]						
No	-	-	-	-	1	1
Yes					1.35 (1.03-1.79)	1.47 (1.07-2.03)
Anxiety Index	-	-	-	-	1.01 (1.00-1.01)	1.00 (1.01-1.01)
Stress	-	-	-	-	1.02 (1.01-1.05)	1.01 (0.96-1.04)
Depression Scale	-	-	-	-	1.01 (1.00-1.04)	1.00 (1.01-1.06)
Limiting	-	-	-	-	1.03 (1.00-1.01)	0.85 (0.81-0.88)
All or nothing	-	-	-	-	1.02 (1.01-1.05)	1.04 (1.01-1.08)

*RRR (95%, CI) *P*

Includes only variables collected at 15±1 weeks' gestation (mode of delivery excluded)

[a]Reference category for predictors were used to take a more positive approach by focusing on factors that improve chances of moderate or high physical activity.

[b]Reference category: low physical activity level; [c]Missing values; [d]1 denotes reference category; [e]BMI category defined as World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25-29.9kg/m^2), obese (≥30kg/m^2) – *underweight and normal were collapsed together for this analysis*

DISCUSSION

Women aged 30-34 years had increased probability of being in the high physical activity subgroup (vs. the low) relative to women <25 years of age. Women with a higher educational level, in a higher social class and in the obese BMI category (>30kg/m^2) had increased probability of being in the moderate physical activity subgroup (vs. the low). Non-smokers were more likely to be in the high physical activity relative to smokers and women who consumed the recommended five servings of fruit and veg per day and at least 1 serving of oily fish per week were more likely to be in the high physical activity subgroup.

Women aged 30-34 years had increased probability of being in the high physical activity subgroup (vs. the low). This is noteworthy given that other studies have reported higher levels of physical activity among younger age groups[13]. Consistent with previous studies on physical activity, pregnant women with a higher educational level and in a higher social class were more likely to engage in moderate levels of physical activity[13, 30, 31]. Similar to other studies, factors associated with exercise during pregnancy include income level, no other children at home, white ethnicity and activity prior to pregnancy [14]. Women with a high education may have access to more information, may be aware of the recommended guidelines and have more time for physical activity during pregnancy[30, 32]. From a public health perspective, a key concern is social inequalities in physical activity, as physical activity participation varies by socioeconomic status, favouring those in a higher social class[33]. Women that don't achieve a high level of education and are of a lower social class are less active and should be the focus of intervention efforts. A previous study showed that women with high pre-pregnancy BMI were less active than women with a low pregnancy BMI[30]. By contrast, the present study showed that pregnant women in the obese BMI category (BMI >30kg/m^2) had increased probability of being in the moderate physical activity subgroup (vs. the low). The relationship between BMI and physical activity observed in this and in other studies is complex. Obese women may be more likely to engage in less strenuous activity or these women may have over-reported their moderate physical activity levels due to the unclear descriptions of physical activity in the survey questions. Moreover, it could reflect perceived exertion where heavier women find themselves performing activity for which they feel like they are exerting themselves, relative to lighter women. Previous interventions for improving physical activity for pregnant women have focused on high risk groups such as obese women[34]. Non-smokers were more likely to be in the high physical activity subgroup relative to smokers, which is

consistent with other studies [31, 35]. Furthermore, women who consumed the recommended five servings of fruit and veg per day and at least 1 serving of oily fish per week were more likely to be in the high physical activity subgroup which indicates some awareness around healthy lifestyle behaviours during pregnancy. Dolan and Galizzi 2015, state that no behaviour sits in a vacuum, and one healthy behaviour can greatly affect another[36]. Furthermore, exercise and fruit and veg consumption have been identified as being in the same behavioural cluster [37] and perhaps explains a potential spill over effect to physical activity as women are already engaging in a number of healthy behaviours. Women who drank alcohol during pregnancy were more likely to be in the moderate physical activity subgroup. This coexistence of healthy and unhealthy behaviours was also identified in other studies[38]. Similar results were found in an Irish sample of adults aged 18 years and over, where the majority of moderate drinkers reported high levels of physical activity[39].

This analysis uses data from one of the largest studies of pregnant women (SCOPE). Furthermore, the population-based nature of the study allowed the estimation of the associations of a variety of social, biological, behavioural and psychological factors in a more representative sample than is often possible. Future research should find and use a better measure of physical activity to accurately assess physical activity levels and investigate the frequency, duration and intensity. While demographic correlates of physical activity are informative, they are largely un-modifiable. However, increased understanding of these correlates can be used to guide the development of interventions and to identify those who need the intervention, in this case, those with a low educational attainment and lower socioeconomic backgrounds.

Limitations of this study

This work is secondary analysis of data collected with an observational study design. Inherent to the nature of the secondary analysis, the available data was not collected to address this particular research question. Furthermore, most of the data on maternal lifestyle factors were based on self-report and is susceptible to biased reporting of the lifestyle behaviours and physical activity. Lifestyle factors in the SCOPE study were based on a range of questions from a non-validated questionnaire which should be acknowledged in order to interpret our results. Original survey questions on physical activity including vigorous exercise, moderate exercise and recreational walking used descriptions such as

breathing and panting. Social desirability bias may have thus led to women over-reporting their physical activity levels. Although self-report has capacity to over or underestimate true physical activity level, the use of daily exercise leading to heavy breathing or being out of breath has been used in other studies[40]. A number of variables were re-categorised for the analysis, easy interpretation and presentation of results [41]. However, by doing this, some information is lost, so caution must be used when interpreting the results as the statistical power to detect a relation between the variables and the physical activity outcome was reduced. Ethnicity needs to be interpreted with caution due to the low numbers of non-Caucasian women. However, the predominance of Caucasian women reflects the demographic profile of females aged 15-44 years in Ireland [42]. In order to create a more robust indicator for this study, latent class analysis was conducted to classify pregnant women's physical activity subgroup based on multiple survey questions. The resulting classification should then be less prone to error than classifying participants based on any single question, but given that there is no gold-standard to compare to, we must still rely on our subjective interpretation of the classification. Furthermore, the data from this study does not illustrate exercise conditions throughout pregnancy or the variation in exercise that may occur from trimester to trimester. Previous research advocates for the continuation of pre-pregnancy and early pregnancy physical activity levels into later pregnancy [43]. Therefore, longitudinal follow up is warranted in future studies.

CONCLUSION

This study identifies the links between social, biological, behavioural and psychological factors and physical activity level during pregnancy in a healthy pregnant population. The findings highlight some key potential links including those of a young maternal age, those with a low education level and those from a low socioeconomic background and physical activity. It also highlights potential behavioural clusters and spill over effects to physical activity. These factors should be considered for future interventions to improve physical activity levels during pregnancy.

List of abbreviations

SCOPE, Screening for Pregnancy End Points; RRR, Relative Risk Ratio; ACOG, American Congress of Obstetricians and Gynaecologists; BMI, body mass index; UK, United Kingdom; USA, United States of America; CUMH, Cork University Maternity Hospital; STROBE, strengthening the reporting of observational studies in epidemiology; AIC, Akaike information criterion; BIC, Bayesian information criterion; SEI, Socioeconomic index; STAI, State Trait Anxiety Index; PSS, Perceived Stress Scale; EPDS, Edinburgh Postnatal Depression Scale

Figure and Table legend

Figure 1: Biopsychosocial model for physical activity using data from the Irish cohort of SCOPE

Figure 2: Flow diagram for SCOPE Ireland

Table 1: Social, biological, behavioural and psychological indicators, by physical activity subgroup

Table 2: Hierarchical multinomial logistic regression

Supplementary data

File 1: STROBE statement

File 2: Psychological well-being and their interpretations

File 3: Unadjusted associations between social, biological, behavioural and psychological indicators and moderate or high levels of physical activity levels in pregnancy

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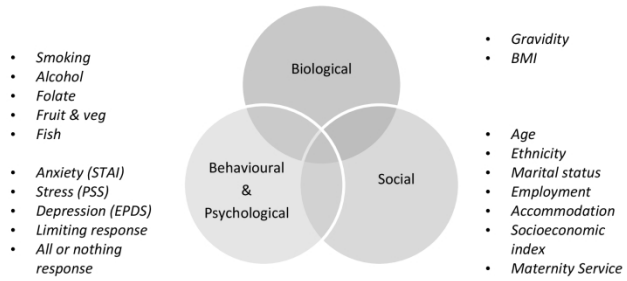
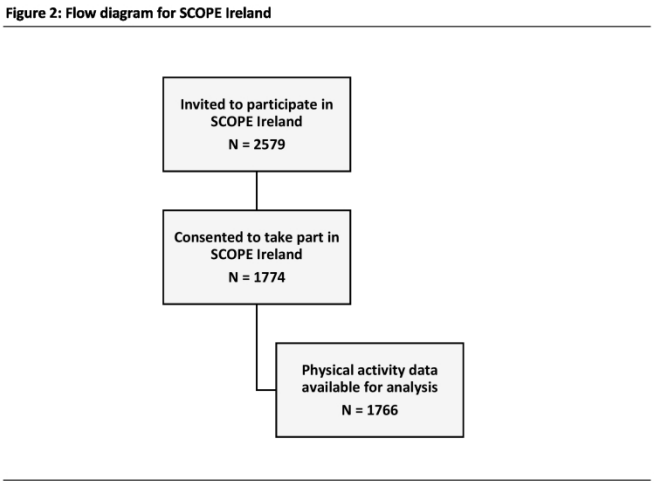
Figure 1: Biopsychosocial model for physical activity using data from the Irish cohort of SCOPE



Biopsychosocial model for physical activity using data from the Irish cohort of SCOPE

209x297mm (300 x 300 DPI)



Flow diagram for SCOPE Ireland

209x297mm (300 x 300 DPI)

STROBE (Strengthening The Reporting of OBservational Studies in Epidemiology) Checklist

A checklist of items that should be included in reports of observational studies. You must report the page number in your manuscript where you consider each of the items listed in this checklist. If you have not included this information, either revise your manuscript accordingly before submitting or note N/A.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Section and Item	Item No.	Recommendation	Reported on Page No.
Title and Abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/Rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			
Study Design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	N/A
		Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	N/A
		Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants	5-7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed	N/A
		Case-control study—For matched studies, give matching criteria and the number of controls per case	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7

Section and Item	Item No.	Recommendation	Reported on Page No.
Data Sources/ Measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-7
Bias	9	Describe any efforts to address potential sources of bias	N/A
Study Size	10	Explain how the study size was arrived at	7
Quantitative Variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-7
Statistical Methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-12
		(*b*) Describe any methods used to examine subgroups and interactions	7-12
		(*c*) Explain how missing data were addressed	Table 1
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	N/A N/A 7-12
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Table 1
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive Data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-12, Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome Data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	N/A
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	7-12

Section and Item	Item No.	Recommendation	Reported on Page No.
Main Results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-12
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other Analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key Results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	12-15
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Once you have completed this checklist, please save a copy and upload it as part of your submission. DO NOT include this checklist as part of the main manuscript document. It must be uploaded as a separate file.

Supplementary file 2: Psychological well-being and their interpretations; adapted from McCarthy et al[27]

Psychological and behavioural scales	Score range and interpretation
Short form of the State Trait Anxiety Index (STAI)[24]	Short –form STAI scores 6-24 converted to a score range of 20-80 to mimic the full version of the STAI, with high scores indicating high state anxiety (i.e. current anxiety)
Perceived Stress Scale (PSS)[25]	0-40, with high scores representing higher perceived stress (feelings of lack of control)
Edinburgh Postnatal Depression Scale (EPDS)[26]	As a continuous measure (0-30) where a higher score indicates a higher probability of depression
Behavioural response to pregnancy scale[27]	Two subscales: 1. Limiting/resting behaviour (0-20)[a] **2.** All-or-nothing behaviour (0-28)[b]

[a]***Limiting response includes:*** *avoiding exercise, life on hold, avoiding usual activities, going to bed during the day, not being able to do usual level of activities.*

[b]***All-or-nothing response includes:*** *overdoing and needing to rest, pushing oneself, carrying on as normal, doing too much.*

Supplementary file 3: Unadjusted associations for moderate or high levels of physical activity levels

Variable	Physical Activity Subgroups			
	Moderate[a] (n =960)		High[a] (n= 413)	
Age category				
<25 years	1[d]		1	
25-29 years	2.35 (1.63-3.41)	0.000	2.02 (1.26-3.22)	<0.0001
30-34 years	2.70 (1.89-3.85)	0.000	3.07 (1.97-4.78)	<0.0001
≥ 35 years	2.48 (1.58-3.89)	0.000	2.62 (1.52-4.54)	<0.0001
Ethnicity				
Non-Caucasian	1		1	
Caucasian	1.62 (0.84-3.13)	0.155	5.42 (1.56-18.88)	<0.0001
Marital status				
Single	1		1	
Married/partner	2.17 (1.54-3.07)	0.000	2.03 (1.54-3.07)	<0.0001
Education				
Schooling ≤12 years	1		1	
Schooling >12 years	2.09 (1.52-2.88)	0.000	1.96 (1.32-2.90)	<0.0001
Employment status				
Not working	1		1	
Working	2.07 (1.44-2.96)	0.000	1.28 (0.86-1.91)	0.230
Accommodation				
Other	1		1	
Own house	1.72 (1.35-2.19)	0.000	1.77 (1.35-2.36)	<0.0001
Socioeconomic index				
<24	1		1	
≥24	1.65 (1.23-2.21)	0.001	1.73 (1.21-2.47)	<0.0001
Maternity service[b]				
Private	1		1	
Public	0.61 (0.46-0.82)	0.001	0.65 (0.47-0.92)	<0.0001
BMI category[e]				
Normal	1		1	
Overweight	1.08 (0.83-1.42)	0.559	0.99 (0.73-1.36)	0.973
Gravidity[b]				
1 pregnancy	1		1	
>1 Pregnancy	0.82 (0.60-1.13)	0.221	0.90 (0.62-1.31)	0.592
Mode of delivery[c]				
C-section	1		1	
Vaginal birth	0.95 (0.73-1.24)	0.732	1.11 (0.81-1.52)	0.512
Smoking				
Smoker	1		1	
Non-smoker	1.56 (1.21-2.01)	0.001	1.65 (1.22-2.24)	<0.0001
Alcohol				
Drinker	1		1	
Non-drinker	0.63 (0.48-0.83)	0.001	0.67 (0.48-0.94)	<0.0001
Folic-acid supplement[b]				
No	1		1	
Yes	1.59 (1.24-2.03)	0.000	1.68 (1.25-2.26)	<0.0001
Five a day[b]				
No	1		1	
Yes	1.57 (1.07-2.32)	0.022	2.30 (1.51-3.50)	<0.0001
Fish[b]				
No	1		1	
Yes	1.41 (1.08-1.84)	0.012	1.60 (1.18-2.17)	<0.0001
Anxiety Index	0.99 (0.98-1.00)	0.003	0.99 (0.98-1.00)	<0.0001
Perceived Stress Scale	0.98 (0.97-1.00)	0.084	0.97 (0.95-1.00)	<0.0001
Depression Scale	0.96 (0.94-0.99)	0.003	0.94 (0.95-0.97)	<0.0001
Limiting response	0.94 (0.91-0.96)	0.000	0.86 (0.83-0.89)	<0.0001
All or nothing response	1.02 (1.00-1.04)	0.215	1.02 (0.99-1.05)	0.260

[a]Reference category: low physical activity level; [b]Missing values; [c]Recoded at birth [d]1 denotes reference category [e]BMI category World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2)

BMJ Open

Social, biological, behavioural and psychological factors related to physical activity during early pregnancy in the Screening for Pregnancy Endpoints (Cork, Ireland) cohort study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-025003.R2
Article Type:	Research
Date Submitted by the Author:	28-Mar-2019
Complete List of Authors:	Flannery, Caragh; National University of Ireland Galway, School of Psychology, Health Behaviour Change Research Group ; University College Cork, School of Public Health Dahly, Darren; University College Cork, School of Public Health ; University College Cork, Health Research Board, Clinical Research Facility Cork Byrne, Molly; National University of Ireland Galway, School of Psychology, Health Behaviour Change Research Group Khashan, Ali; University College Cork, School of Public Health; University College Cork, The Irish Centre for Fetal and Neonatal Translational Research (INFANT) Mc Hugh, Sheena; University College Cork, School of Public Health Kenny, Louise; University of Liverpool School of Life Sciences, Department of Women's and Children's Health McAuliffe, Fionnuala; University College Dublin, UCD Perinatal Research Centre, School of Medicine; University College Dublin, National Maternity Hospital Kearney, Patricia; University College Cork, School of Public Health
Primary Subject Heading:	Public health
Secondary Subject Heading:	Obstetrics and gynaecology, Epidemiology
Keywords:	PUBLIC HEALTH, Pregnancy, Physical activity, Exercise

Title: 'Social, biological, behavioural and psychological factors related to physical activity during early pregnancy in the Screening for Pregnancy Endpoints (Cork, Ireland) cohort study'

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ABSTRACT

Objectives: To identify the social, biological, behavioural and psychological factors related to physical activity (PA) in early pregnancy.

Design: Secondary analysis of data from a prospective cohort study.

Setting: Cork, Ireland

Participants: Nulliparous women with singleton pregnancies were recruited and then interviewed at 15±1 weeks' gestation.

Primary and secondary outcomes: The bio-psychosocial model identified factors including: social (age), biological (body mass index), behavioural (diet) and psychological (anxiety) at 15±1 weeks' gestation. PA subgroups were identified based on a latent class analysis of their responses to a set of questions about the amount and intensity of activity they were engaging in during the pregnancy. Associations were estimated with multivariable multinomial logistic regression models.

Results: From a total of 2579, 1774 (69%) women were recruited; ages ranged from 17-45 years. Based on a combination of model fit, theoretical interpretability, and classification quality, the latent class analyses identified three PA subgroups: *low* PA (n = 393); *moderate* PA (n = 960); and *high* PA (n = 413). The fully adjusted model suggests non-smokers, and consumers of fruit and veg were more likely to be in the high PA subgroup (vs. low). Women with more than 12 years of schooling and a higher socioeconomic status were more likely to be in the moderate PA subgroup (vs. low).

Conclusion: The findings highlight potential links between physical activity, a low education level, and a low socioeconomic background. These factors should be considered for future interventions to improve low physical activity levels during pregnancy.

Key Words: Physical Activity, Exercise, Pregnancy

Word count: 3957

Strengths and limitations

- Multivariable multinomial logistic regression models were used to estimate the associations between physical activity and social, biological, behaviour and psychological factors in pregnancy within an Irish context.
- Maternal lifestyle factors were based on self-report and therefore subject to error.
- Latent class analysis was used to identify mutually exclusive subgroups in order to create a physical activity outcome measure that best describes the observed set of responses.

Funding

This work was supported by Health Research Board Ireland, (CSA/2007/2). LCK and ASK are supported by a Science Foundation Ireland Program Grant for INFANT (12/RC/2272). CF is funded by the Health Research Board SPHeRE/2013/1.

Competing interests

The authors declare that they have no competing interests.

Author's contributions

CF, ASK, DD and SMH formulated the overarching study aims and methodology. Data management was controlled by CF, who selected appropriate variables, cleaned and maintained the research data. DD conducted the latent class analysis and CF conducted the formal analysis, running the multinomial logistic regression. CF wrote the initial draft of the paper. MB, FMA, PMK and LCK contributed to successive drafts, reviewing and editing. All authors read and approved the final manuscript.

Checklist STROBE checklist

Ethical approval and consent to participate

The SCOPE study was approved by the local ethics committee (Cork ECM5 (10) 05/02/08), all women provided written informed consent and the data was anonymised. For this study, research approval was obtained from the SCOPE team (RAF 3.66) and from the University College Cork, Office of Technology Transfer RU/2015/203.

Data statement

All data generated or analysed during the current study is available from the SCOPE team on reasonable request.

INTRODUCTION

Physical activity is defined as 'any bodily movement produced by skeletal muscles that requires energy expenditure' including leisure time physical activity, walking, household chores, games, sports or planned exercise, in the context of daily, family, and community activities[1]. National and international guidelines for pregnancy recommend 30 minutes or more of daily moderate physical activity, or 150 minutes of moderate physical activity spread throughout the week [2-6]. Regular physical activity during pregnancy is beneficial for both mother and fetus, as it helps to prevent complications, limit weight gain, and decrease the risk of gestational diabetes[7]. Despite these significant health benefits, physical activity is lower among pregnant women [8, 9]. Studies using self-report measures of physical activity in the UK and USA estimate that only 3–15% of pregnant women meet current guidelines, compared to 24–26% of non-pregnant women[10, 11]. In Ireland, only one-fifth of pregnant women meet physical activity guidelines, and over 10% of pregnant women report no physical activity[9].

Consequently, there is a need for effective strategies to increase activity during pregnancy. Recognising and understanding the correlates of physical activity, as well explaining how these correlates may influence subsequent behaviour, is fundamental to intervention development and implementation.

Previous observational studies have found that demographic factors such as age, income and education are important correlates of participation in physical activity during pregnancy [12-14]. Furthermore, factors such as body mass index (BMI) has been associated with both increased and decreased level of exercise during pregnancy compared to pre-pregnancy levels[12]. Of women who engaged in a regular exercise regime, those most likely to quit by the 3rd trimester were women who had a high BMI and those who had gained more weight during pregnancy[12]. Social factors like unemployment have been shown to influence physical activity levels[15, 16] with higher education, a higher income and not having children being predictors of high exercise participation[14]. These studies have used various physical activity measures such as recreational activity, occupation or household activity as opposed to total physical activity. Therefore, a further understanding of physical activity level is essential in order to increase activity during pregnancy.

Using data from a prospective Irish cohort, this study aims to identify the different social, biological, behavioural and psychological factors that are linked with physical activity levels during pregnancy.

METHODS

Study Design and population

Secondary analysis of the Irish data from the prospective cohort study Screening for Pregnancy End Points (SCOPE). Scope is multicentre cohort study (Cork, Auckland, Adelaide, London, Leeds, and Manchester) with the main aim of developing screening tests to predict pre-eclampsia, small for gestational age infants and spontaneous pre-term birth as previously described[17-19]. In brief, healthy nulliparous women with singleton pregnancies were recruited and then interviewed at 15±1 weeks' gestation from Cork University Maternity Hospital (CUMH), Ireland (n=1774) between March 2008 and February 2011 with the last baby born in August 2011. At 15±1 and 20± weeks' gestation comprehensive data were collected on social factors including age, marital status, ethnicity, accommodation, socioeconomic index; behavioural and psychological factors before conception and during pregnancy. Women were followed prospectively and research midwives collected data on pregnancy outcomes and measurements of the baby. For the purpose of this study, only data collected at 15±1 is analysed. The STROBE checklist for cohort studies was used to inform reporting of the findings (Supplementary file 1).

Patient and Public Involvement

This is secondary analysis using data from the SCOPE study. Pregnant women were not directly involved in the design or administration of this analysis.

Outcome measure

In three separate questions, participants were asked how often they engaged in vigorous exercise *(exercise which made you breathe harder or pant)*, moderate exercise *(exercise which did not make you breathe harder or pant)*, and recreational walking *(walking for recreation or exercise)*. Responses to each of the three questions were self-reported and coded as *never; once a week; 2-3 times a week; 4-6 times a week; daily; more than twice daily*. Latent class analysis was used to identify mutually exclusive subgroups in the sample of participants based on these three categorical survey items[20]. The central challenge to any latent class model is to select the appropriate number of classes (or subgroups) that best describe the observed set of responses. Because the number of latent class must be set by the user, we estimated a series of models where the number of latent classes ranged from 1 to 6. The authors then met to discuss the results and a final number of latent classes were selected based on model fit statistics (using Akaike information criterion (AIC) and Bayesian information criterion (BIC)), parsimony, theoretical interpretability, and classification

quality. Once the final model was chosen, participants were assigned to their most likely class (i.e. their modal assignment). Latent class models were estimated using MPlus version 8.0.

Covariates

Social measures

Characteristics included: maternal age (*years or age category; <25 year, 25-29 years, 30-34 years, ≥35years*); ethnicity (*Caucasian vs. non-Caucasian*); relationship status (*single, married/partner*); employment status (*working vs. not working*); accommodation (*own home or other*); education (*≤ 12 years of schooling vs. > 12 years of schooling*) and type of maternity care services (*Public* vs. *Private)* used. Socioeconomic index (SEI) was based on an occupation-based measure of socio-economic status 'New Zealand SEI' (*<24 vs. ≥24*) with higher values reflecting greater social status[21].

Biological measures

Gravidity (*1* vs. *> 1*) was collected at 15±1 weeks' gestation. Body mass index (BMI) was calculated from pregnancy weight (kg) divided by measured height squared (m2) from the first SCOPE visit at 15±1 weeks' gestation. BMI was categorised based on World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5-24.9kg/m^2), overweight (≥25-29.9kg/m^2), obese (≥30kg/m^2)[22].

Psychological and behavioural measures

Based on participant reported consumption, alcohol measured as drinks per week at 15±1 weeks' gestation *(no drinks; 1-2 drinks; 3-7 drinks; 8-14 drinks; >14 drinks)* was categorised as (*drinkers (≥ 1 drink) vs. non-drinkers (no drink)*); and smoking per day at 15±1 weeks' gestation *(no smoking; 1-5 cigarettes; 6-10 cigarettes; >10 cigarettes)* was categorised as (*smokers (≥1 cigarettes) vs. non-smokers (no smoking)*). Women were asked about pre-pregnancy folic-acid supplementation *(no, yes),* and their responses *(dose)* were dichotomized as those meeting the recommended 400 µg vs. those who did not (*Yes* vs. *No*). The questionnaire administered at 15±1 weeks' gestation asked women to report the frequency with which they consumed fruit, vegetables and fish in the first 15 weeks of pregnancy. These responses were used to determine whether they were meeting the recommended five servings of fruit and veg per day (*Yes* vs. *No*), and at least 1 serving of oily fish per week (*Yes* vs. *No*).

Maternal anxiety was assessed using the short form of the State Trait Anxiety Index (STAI)[23], how much stress the woman experienced measured using the Perceived Stress Scale (PSS)[24] and depressive symptoms were assessed using the Edinburgh Postnatal Depression Scale (EPDS)[25].

Pregnancy related behaviour was measured using the behavioural response to pregnancy scale: 'all or nothing' response describes an individual who pushes oneself to keep going until they find it physically impossible; 'Limiting' response describes an individual who avoids daily activities[26]. See Supplementary file 2 for their interpretations[27].

Statistical analysis

Secondary analysis was performed using the Irish data from SCOPE in Stata (Version 13). The bio-psychosocial model was used to identify factors that are associated with PA in early pregnancy. This model recognises the influences of the biological, psychological, and social dimensions of a person's life (Figure 1)[28]. Associations between participant characteristics and the physical activity subgroups identified in the latent class analysis were explored using chi-squared test for categorical and ANOVA for continuous variables. Unadjusted multinomial logistic regression was conducted to examine the association between covariates and physical activity level. See Supplementary file 3 for the unadjusted associations. Multivariable, multinomial logistic regression was conducted using a hierarchical approach[29] whereby model 1 included the social factors, model 2 added the biological factors, and model 3 was further adjusted for the behavioural and psychological factors. All variables are included in the adjusted model. Estimated coefficients are reported as Relative Risk Ratios (RRR) with 95% confidence intervals (CI) using those who reported low physical activity as the reference category. This is because the exponentiated coefficient in multinomial logistic regression is the ratio of two relative risks (RRR) and should not be interpreted as an odds ratio (OR).

Insert Figure 1 here

RESULTS

Sample characteristics

A total of 2579 nulliparous women were invited to participate in the SCOPE Irish study, 1774 (69%) consented to take part (Figure 2). Ages ranged from 17 to 45 (mean age 30, standard deviation 4.5). The SCOPE Ireland women were predominantly Caucasian (n=1733, 98%), married (n=1584, 89%), with > 12 years of schooling (n=1207, 68%), and higher socioeconomic status (n=1469, 83%). The estimated proportions of women in each BMI category were, normal (n=1058, 60%), overweight (n=495, 28%) and obese (n=221, 12%).

Insert Figure 2 here

Physical activity levels

Physical activity data was available for 1766 women. Based on a combination of model fit, parsimony, theoretical interpretability, and classification quality, the authors agreed that a three-class model was the most appropriate one (see supplementary file 4). The three physical activity subgroups thus identified were characterised as follows: *low* levels of physical activity (n=393); *moderate* levels of physical activity (n=960); and *high* levels of physical activity (n=413). Based on chi-squared test and ANOVA, physical activity subgroups were crudely associated with most of the variables considered (Table 1).

Table 1: Social, biological, behavioural and psychological indicators, by physical activity subgroup

Variable		Physical Activity Subgroup (n=1766)		
	n	Low (n =393)	Moderate (n=960)	High (n=413)
Maternal Age (years)	1774			
Mean (SD)		28.8 (5.0)	30.2 (4.3)	30.4 (4.2)
Ethnicity				
Non-Caucasian	1774	15 (36.6)	23 (56.1)	3 (7.3)
Caucasian		378 (21.9)	937 (54.3)	410 (23.8)
Marital status				
Single	1774	67 (35.6)	83 (44.2)	38 (20.2)
Married/partner		326 (20.7)	877 (55.6)	326 (20.7)
Education				
Schooling ≤12 years	1774	79 (34.5)	103 (45.0)	47 (20.5)
Schooling >12 years		314 (20.4)	857 (55.8)	366 (23.8)
Employment status				
Not working	1774	60 (31.9)	77 (41.0)	51 (27.1)
Working		333 (21.1)	883 (56.0)	362 (22.9)
Accommodation				
Other	1774	173 (28.8)	301 (50.1)	127 (21.1)
Own house		220 (18.9)	659 (56.6)	286 (24.6)
Socioeconomic index				
<24	1774	92 (30.3)	150 (49.3)	62 (20.4)
≥24		301 (20.6)	810 (55.4)	351 (24.0)
Maternity service[a]				
Private	1754	72 (16.5)	258 (59.2)	106 (24.3)
Public		317 (24.1)	696 (52.8)	305 (23.1)
BMI category[c]				
Underweight	1774	5 (23.8)	11 (52.4)	5 (23.8)
Normal		236 (22.8)	545 (52.7)	253 (24.5)
Overweight		108 (21.9)	270 (54.8)	115 (23.3)
Obese		44 (20.2)	134 (61.5)	40 (18.4)
Gravidity[a]				
1 pregnancy	1754	322 (21.7)	815 (55.0)	346 (23.3)
>1 Pregnancy		67 (24.7)	139 (51.3)	65 (24.0)
Mode of delivery[b]				
C-section	1773	105 (22.3)	265 (56.1)	102 (21.6)
Vaginal birth		288 (22.3)	694 (53.7)	311 (24.1)
Smoking				
Smokers	1774	137 (28.4)	245 (50.7)	101 (20.9)
Non-smokers		256 (20.0)	715 (55.7)	312 (24.3)
Alcohol				
Drinkers	1774	292 (20.6)	778 (55.7)	335 (23.7)
Non-drinkers		101 (28.8)	172 (49.0)	78 (22.2)
Folic-acid supplement[a]				
No	1754	157 (28.0)	285 (50.9)	118 (21.1)
Yes		232 (19.4)	669 (56.0)	293 (24.5)
Five a day[a]				
No	1754	353 (23.4)	822 (54.5)	333 (22.1)
Yes		36 (14.6)	132 (53.7)	78 (31.7)

Table 1: Social, biological, behavioural and psychological indicators, by physical activity subgroup (continued)

Fish[a]				
No	1754	291 (24.2)	647 (53.7)	267 (22.2)
Yes		98 (17.9)	307 (55.9)	144 (26.2)
Anxiety Index	1774	33 (27-43)	33 (27-40)	30 (23-40)
Perceived Stress Scale	1774	14 (9-19)	13 (9-18)	13 (8-17)
Depression Scale	1774	6 (3-10)	6 (3-19)	5 (2-9)
Limiting response	1774	9 (5-12)	8 (6-10)	6 (3-9)
All or nothing response	1774	7 (4-11)	8 (5-11)	8 (5-11)

Data are means (SD) number (%) and median (interquartile range). Kruskal-Wallis H or the Chi-square test.
[a]Missing values; [b]Recoded at birth; [c]BMI category defined as World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5-24.9kg/m^2), overweight (≥25-29.9kg/m^2), obese (≥30kg/m^2)

Multivariable logistic regression findings

In the unadjusted multinomial logistic regression, the majority of social and behavioural factors where linked to either the moderate or high physical activity subgroups or both (See Supplementary file3). Therefore, all variables were included in the final model. Table 2 presents the findings of the multivariable logistic regression analyses with low physical activity as the reference category.

Social, biological, behavioural and psychological

In model 1, social factors such as employment, accommodation and type of maternity service were not statistically significant for moderate physical activity (vs. low) or high physical activity (vs. low). Furthermore, in model 2, biological factors BMI and gravidity were not statistically significant for moderate physical activity (vs. low) or high physical activity (vs. low).

Results from the fully adjusted model (Table 2, model 3) suggest, social factors such as women aged 30-34 (RRR 2.27 [95% CI: 1.23-4.22]) were associated with high physical activity (vs. low), with non-Caucasians being less likely to be in the high physical activity subgroup (vs. low) (RRR 0.23 [95% CI: 0.06-0.86]). Similarly, having > 12 years of schooling (RRR 1.55 [95% CI: 1.06-2.26]) and a higher socioeconomic status (≥24) (RRR 1.46 [95% CI: 1.05-2.05]) remained associated with moderate physical activity (vs. low). Of the biological factors, the relative risk for obese women (BMI >30kg/m^2) would be expected to increase (RRR 1.49 [95% CI: 1.00-2.22]) for moderate physical activity relative to normal (BMI <24 kg/m2) (vs. the low).

Accounting for social and biological factors, women who consumed five portions of fruit and veg a day (RRR 1.90 [95% CI: 1.22-2.96]) and oily fish (RRR 1.47 [95% CI: 1.07-2.03]) where more likely to

be in the high physical activity subgroup (vs. low), relative to those who did not consume fruit and veg or oily fish. Non-smokers were 1.45 times more likely to be in the high physical activity subgroup (vs. the low) relative to those who reported smoking (RRR 1.45 [95% CI: 1.02-2.07]). For women who did not consume alcohol relative to those who drank, the relative risk for moderate physical activity group (vs. the low) would be expected to decrease by a factor of 0.62 (RRR 0.62 [95% CI: 0.45-0.84]).

For psychological factors, the relative risk for moderate physical activity group (vs. the low), for those who reported avoiding exercise as a response to pregnancy would be expected to increase by a factor of 1.03 (RRR 1.03 [95% CI: 1.00-1.01]) and the relative risk for high physical activity group (vs. the low) would be expected to decrease by a factor of 0.85 (RRR 0.85 [95% CI: 0.81-0.88]) (vs. the low). In addition, those who reported pushing oneself as a response to pregnancy were 1.04 times more likely to be in the high physical activity subgroup (RRR 1.04 [95% CI: 1.01-1.08]) (vs. the low).

Table 2: Hierarchical multinomial logistic regression

Variable[a]	Model 1*		Model 2*		Model 3*	
	Moderate[b] (n =960)	High[b] (n= 413)	Moderate[b] (n =960)	High[b] (n= 413)	Moderate[b] (n =960)	High[b] (n= 413)
Age category						
<25 years	1[d]	1	1	1	1	1
25-29 years	1.56 (1.00-2.45)	1.69 (0.96-2.98)	1.55 (0.98-2.44)	1.71 (0.97-3.01)	1.53 (0.96-2.44)	1.69 (0.94-3.06)
30-34 years	1.55 (0.96-2.50)	2.31 (1.28-4.16)	1.55 (0.96-2.51)	2.33 (1.30-4.19)	1.49 (0.91-2.45)	2.27 (1.23-4.22)
≥ 35 years	1.48 (0.85-2.56)	1.96 (1.01-3.81)	1.48 (0.85-2.57)	2.00 (1.02-3.91)	1.42 (0.80-2.51)	1.98 (0.97-4.01)
Ethnicity						
Caucasian	1	1	1	1	1	1
Non-Caucasian	0.89 (0.43-1.86)	0.24 (0.06-0.86)	0.89 (0.43-1.86)	0.23 (0.063-0.85)	0.96 (0.46-2.11)	0.23 (0.06-0.86)
Marital status						
Single	1	1	1	1	1	1
Married/partner	1.35 (0.87-2.11)	1.31 (0.76-2.25)	1.37 (0.88-2.14)	1.32 (0.76-2.27)	1.25 (0.79-1.98)	1.06 (0.59-1.88)
Education						
Schooling ≤12 years	1	1	1	1	1	1
Schooling >12 years	1.73 (1.20-2.50)	1.49 (0.96-2.30)	1.65 (1.14-2.39)	1.48 (0.95-2.30)	1.55 (1.06-2.26)	1.35 (0.85-2.14)
Employment status						
Not working	1	1	1	1	1	1
Working	1.44 (0.95-2.18)	0.78 (0.49-1.26)	1.48 (0.98-2.26)	0.78 (0.48-1.25)	1.40 (0.92-2.14)	0.66 (0.40-1.08)
Accommodation						
Other	1	1	1	1	1	1
Own house	1.02 (0.75-1.40)	1.06 (0.73-1.53)	1.02 (0.75-1.40)	1.05 (0.73-1.53)	0.99 (0.71-1.37)	1.01 (0.68-1.48)
Socioeconomic						
<24	1	1	1	1	1	1
≥24	1.40 (1.01-1.93)	1.38 (0.93-2.03)	1.44 (1.04-2.01)	1.36 (0.92-2.01)	1.46 (1.05-2.05)	1.47 (0.98-2.21)
Maternity service[c]						
Private	1	1	1	1	1	1
Public	0.82 (0.60-1.12)	0.90 (0.63-1.30)	0.80 (0.58-1.10)	0.91 (0.63-1.30)	0.80 (0.58-1.10)	0.93 (0.64-1.36)
BMI category [e]						
Underweight/Normal	-	-	1	1	1	1
Overweight			1.09 (0.83-1.44)	0.97 (0.71-1.35)	1.23 (0.85-1.50)	1.04 (0.74-1.45)
Obese			1.45 (0.98-2.15)	0.91 (0.56-1.46)	1.49 (1.00-2.22)	0.96 (0.59-1.57)
Gravidity[c]						
1 pregnancy	-	-	1	1	1	1

>1 Pregnancy			0.79 (0.57-1.10)	0.88 (0.56-1.46)	0.87 (0.62-1.22)	1.06 (0.71-1.58)
Smoking						
Smokers	-	-	-	-	1	1
Non-smokers					1.34 (1.00-1.80)	1.45 (1.02-2.07)
Alcohol						
Drinkers	-	-	-	-	1	1
Non-drinkers					0.62 (0.45-0.84)	0.75 (0.52-1.08)
Folic-acid[c]						
No	-	-	-	-	1	1
Yes					1.06 (0.78-1.46)	1.17 (0.80-1.70)
Five a day[c]						
No	-	-	-	-	1	1
Yes					1.41 (0.94-2.11)	1.90 (1.22-2.96)
Fish[c]						
No	-	-	-	-	1	1
Yes					1.35 (1.03-1.79)	1.47 (1.07-2.03)
Anxiety Index	-	-	-	-	1.01 (1.00-1.01)	1.00 (1.01-1.01)
Stress	-	-	-	-	1.02 (1.01-1.05)	1.01 (0.96-1.04)
Depression Scale	-	-	-	-	1.01 (1.00-1.04)	1.00 (1.01-1.06)
Limiting	-	-	-	-	1.03 (1.00-1.01)	0.85 (0.81-0.88)
All or nothing	-	-	-	-	1.02 (1.01-1.05)	1.04 (1.01-1.08)

*RRR (95%, CI) *P*

Includes only variables collected at 15±1 weeks' gestation (mode of delivery excluded)

[a]Reference category for predictors were used to take a more positive approach by focusing on factors that improve chances of moderate or high physical activity.

[b]Reference category: low physical activity level; [c]Missing values; [d]1 denotes reference category; [e]BMI category defined as World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25-29.9kg/m^2), obese (≥30kg/m^2) – *underweight and normal were collapsed together for this analysis*

DISCUSSION

Women aged 30-34 years had increased probability of being in the high physical activity subgroup (vs. the low) relative to women <25 years of age. Women with a higher educational level, in a higher social class and in the obese BMI category (>30kg/m^2) had increased probability of being in the moderate physical activity subgroup (vs. the low). Non-smokers were more likely to be in the high physical activity relative to smokers and women who consumed the recommended five servings of fruit and veg per day and at least 1 serving of oily fish per week were more likely to be in the high physical activity subgroup.

Women aged 30-34 years had increased probability of being in the high physical activity subgroup (vs. the low). This is noteworthy given that other studies have reported higher levels of physical activity among younger age groups[13]. Consistent with previous studies on physical activity, pregnant women with a higher educational level and in a higher social class were more likely to engage in moderate levels of physical activity[13, 30, 31]. Similar to other studies, factors associated with exercise during pregnancy include income level, no other children at home, white ethnicity and activity prior to pregnancy [14]. Women with a high education may have access to more information, may be aware of the recommended guidelines and have more time for physical activity during pregnancy[30, 32]. From a public health perspective, a key concern is social inequalities in physical activity, as physical activity participation varies by socioeconomic status, favouring those in a higher social class[33]. Women with a low education level and those of a lower socio-economic class are less active and should be the focus of intervention efforts. A previous study showed that women with high pre-pregnancy BMI were less active than women with a low pregnancy BMI[30]. By contrast, the present study showed that pregnant women in the obese BMI category (BMI >30kg/m^2) had increased probability of being in the moderate physical activity subgroup (vs. the low). The relationship between BMI and physical activity observed in this and in other studies is complex. Obese women may be more likely to engage in less strenuous activity or these women may have over-reported their moderate physical activity levels due to the unclear descriptions of physical activity in the survey questions. Moreover, it could reflect perceived exertion where heavier women find themselves performing activity for which they feel like they are exerting themselves, relative to lighter women. Previous interventions for improving physical activity for pregnant women have focused on high risk groups such as obese women[34]. Non-smokers were more likely to be in the high physical activity subgroup relative to smokers, which is

consistent with other studies [31, 35]. Furthermore, women who consumed the recommended five servings of fruit and veg per day and at least 1 serving of oily fish per week were more likely to be in the high physical activity subgroup which indicates some awareness around healthy lifestyle behaviours during pregnancy. Dolan and Galizzi 2015, state that no behaviour sits in a vacuum, and one healthy behaviour can greatly affect another[36]. Furthermore, exercise and fruit and veg consumption have been identified as being in the same behavioural cluster [37] and perhaps explains a potential spill over effect to physical activity as women are already engaging in a number of healthy behaviours. Women who drank alcohol during pregnancy were more likely to be in the moderate physical activity subgroup. This coexistence of healthy and unhealthy behaviours was also identified in other studies[38]. Similar results were found in an Irish sample of adults aged 18 years and over, where the majority of moderate drinkers reported high levels of physical activity[39].

This analysis uses data from one of the largest studies of pregnant women (SCOPE). Furthermore, the population-based nature of the study allowed the estimation of the associations of a variety of social, biological, behavioural and psychological factors in a more representative sample than is often possible. Future research should find and use a better measure of physical activity to accurately assess physical activity levels and investigate the frequency, duration and intensity. While demographic correlates of physical activity are informative, they are largely un-modifiable. However, increased understanding of these correlates can be used to guide the development of interventions and to identify those who need the intervention, in this case, those with a low educational attainment and lower socioeconomic backgrounds.

Limitations of this study

This work is secondary analysis of data collected with an observational study design. Inherent to the nature of the secondary analysis, the available data was not collected to address this particular research question. Furthermore, most of the data on maternal lifestyle factors were based on self-report and is susceptible to biased reporting of the lifestyle behaviours and physical activity. Lifestyle factors in the SCOPE study were based on a range of questions from a non-validated questionnaire which should be acknowledged in order to interpret our results. Original survey questions on physical activity including vigorous exercise, moderate exercise and recreational walking used descriptions such as

breathing and panting. Social desirability bias may have thus led to women over-reporting their physical activity levels. Although self-report has capacity to over or underestimate true physical activity level, the use of daily exercise leading to heavy breathing or being out of breath has been used in other studies[40]. A number of variables were re-categorised for the analysis, easy interpretation and presentation of results [41]. However, by doing this, some information is lost, so caution must be used when interpreting the results as the statistical power to detect a relation between the variables and the physical activity outcome was reduced. Ethnicity needs to be interpreted with caution due to the low numbers of non-Caucasian women. However, the predominance of Caucasian women reflects the demographic profile of females aged 15-44 years in Ireland [42]. In order to create a more robust indicator for this study, latent class analysis was conducted to classify pregnant women's physical activity subgroup based on multiple survey questions. The resulting classification should then be less prone to error than classifying participants based on any single question, but given that there is no gold-standard to compare to, we must still rely on our subjective interpretation of the classification. Furthermore, the data from this study does not illustrate exercise conditions throughout pregnancy or the variation in exercise that may occur from trimester to trimester. Previous research advocates for the continuation of pre-pregnancy and early pregnancy physical activity levels into later pregnancy [43]. Therefore, longitudinal follow up is warranted in future studies.

CONCLUSION

This study identifies the links between social, biological, behavioural and psychological factors and physical activity level during pregnancy in a healthy pregnant population. The findings highlight some key potential links including those of a young maternal age, those with a low education level and those from a low socioeconomic background and physical activity. It also highlights potential behavioural clusters and spill over effects to physical activity. These factors should be considered for future interventions to improve physical activity levels during pregnancy.

List of abbreviations

SCOPE, Screening for Pregnancy End Points; RRR, Relative Risk Ratio; ACOG, American Congress of Obstetricians and Gynaecologists; BMI, body mass index; UK, United Kingdom; USA, United States of America; CUMH, Cork University Maternity Hospital; STROBE, strengthening the reporting of observational studies in epidemiology; AIC, Akaike information criterion; BIC, Bayesian information criterion; SEI, Socioeconomic index; STAI, State Trait Anxiety Index; PSS, Perceived Stress Scale; EPDS, Edinburgh Postnatal Depression Scale

Figure and Table legend

Figure 1: Biopsychosocial model for physical activity using data from the Irish cohort of SCOPE

Figure 2: Flow diagram for SCOPE Ireland

Table 1: Social, biological, behavioural and psychological indicators, by physical activity subgroup

Table 2: Hierarchical multinomial logistic regression

Supplementary data

File 1: STROBE statement

File 2: Psychological well-being and their interpretations

File 3: Unadjusted associations between social, biological, behavioural and psychological indicators and moderate or high levels of physical activity levels in pregnancy

File 4: Model fit statistics and three class model definitions

References

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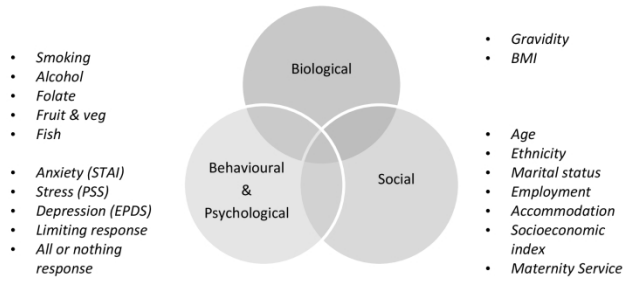
Figure 1: Biopsychosocial model for physical activity using data from the Irish cohort of SCOPE



Biopsychosocial model for physical activity using data from the Irish cohort of SCOPE

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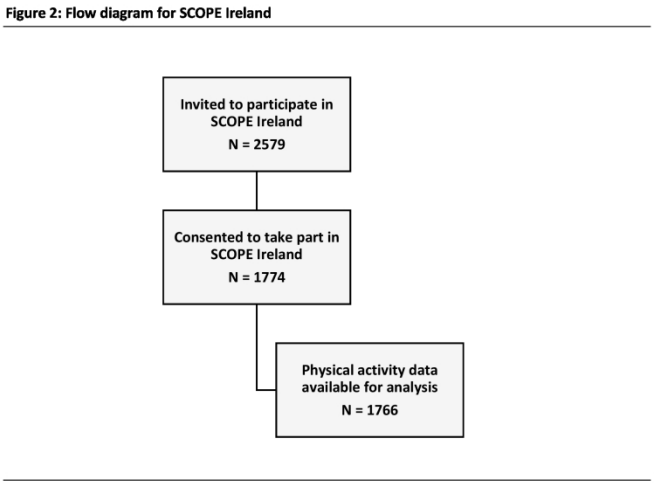

Flow diagram for SCOPE Ireland

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STROBE (Strengthening The Reporting of OBservational Studies in Epidemiology) Checklist

A checklist of items that should be included in reports of observational studies. You must report the page number in your manuscript where you consider each of the items listed in this checklist. If you have not included this information, either revise your manuscript accordingly before submitting or note N/A.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Section and Item	Item No.	Recommendation	Reported on Page No.
Title and Abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/Rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			
Study Design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	N/A
		Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	N/A
		Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants	5-7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed	N/A
		Case-control study—For matched studies, give matching criteria and the number of controls per case	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7

Section and Item	Item No.	Recommendation	Reported on Page No.
Data Sources/ Measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-7
Bias	9	Describe any efforts to address potential sources of bias	N/A
Study Size	10	Explain how the study size was arrived at	7
Quantitative Variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-7
Statistical Methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-12
		(*b*) Describe any methods used to examine subgroups and interactions	7-12
		(*c*) Explain how missing data were addressed	Table 1
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	N/A N/A 7-12
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Table 1
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive Data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-12, Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome Data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	N/A
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	7-12

Section and Item	Item No.	Recommendation	Reported on Page No.
Main Results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-12
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other Analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key Results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	12-15
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Once you have completed this checklist, please save a copy and upload it as part of your submission. DO NOT include this checklist as part of the main manuscript document. It must be uploaded as a separate file.

Supplementary file 2: Psychological well-being and their interpretations; adapted from McCarthy et al[27]

Psychological and behavioural scales	Score range and interpretation
Short form of the State Trait Anxiety Index (STAI)[24]	Short –form STAI scores 6-24 converted to a score range of 20-80 to mimic the full version of the STAI, with high scores indicating high state anxiety (i.e. current anxiety)
Perceived Stress Scale (PSS)[25]	0-40, with high scores representing higher perceived stress (feelings of lack of control)
Edinburgh Postnatal Depression Scale (EPDS)[26]	As a continuous measure (0-30) where a higher score indicates a higher probability of depression
Behavioural response to pregnancy scale[27]	Two subscales: 1. Limiting/resting behaviour (0-20)[a] **2.** All-or-nothing behaviour (0-28)[b]

[a]***Limiting response includes:*** *avoiding exercise, life on hold, avoiding usual activities, going to bed during the day, not being able to do usual level of activities.*

[b]***All-or-nothing response includes:*** *overdoing and needing to rest, pushing oneself, carrying on as normal, doing too much.*

Supplementary file 3: Unadjusted associations for moderate or high levels of physical activity levels

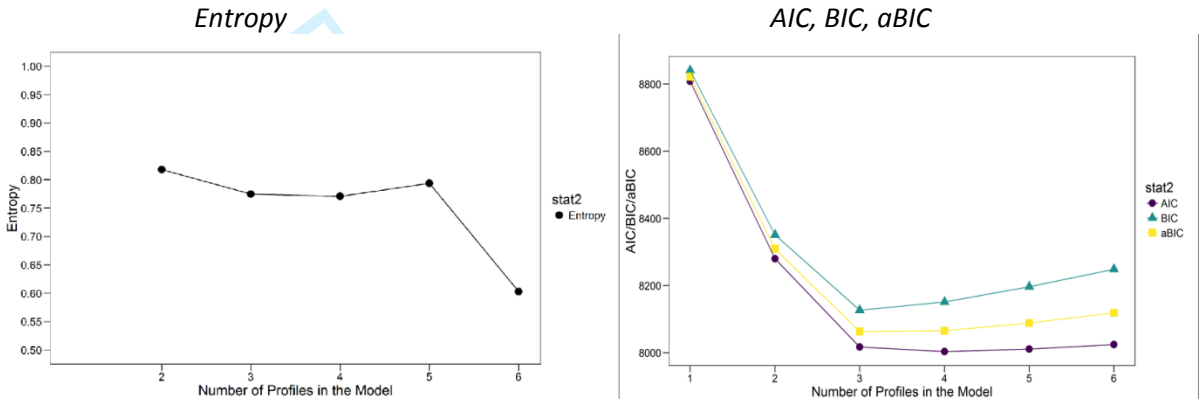
Variable	Physical Activity Subgroups			
	Moderate[a] (n =960)		High[a] (n= 413)	
Age category				
<25 years	1[d]		1	
25-29 years	2.35 (1.63-3.41)	0.000	2.02 (1.26-3.22)	<0.0001
30-34 years	2.70 (1.89-3.85)	0.000	3.07 (1.97-4.78)	<0.0001
≥ 35 years	2.48 (1.58-3.89)	0.000	2.62 (1.52-4.54)	<0.0001
Ethnicity				
Non-Caucasian	1		1	
Caucasian	1.62 (0.84-3.13)	0.155	5.42 (1.56-18.88)	<0.0001
Marital status				
Single	1		1	
Married/partner	2.17 (1.54-3.07)	0.000	2.03 (1.54-3.07)	<0.0001
Education				
Schooling ≤12 years	1		1	
Schooling >12 years	2.09 (1.52-2.88)	0.000	1.96 (1.32-2.90)	<0.0001
Employment status				
Not working	1		1	
Working	2.07 (1.44-2.96)	0.000	1.28 (0.86-1.91)	0.230
Accommodation				
Other	1		1	
Own house	1.72 (1.35-2.19)	0.000	1.77 (1.35-2.36)	<0.0001
Socioeconomic index				
<24	1		1	
≥24	1.65 (1.23-2.21)	0.001	1.73 (1.21-2.47)	<0.0001
Maternity service[b]				
Private	1		1	
Public	0.61 (0.46-0.82)	0.001	0.65 (0.47-0.92)	<0.0001
BMI category[e]				
Normal	1		1	
Overweight	1.08 (0.83-1.42)	0.559	0.99 (0.73-1.36)	0.973
Gravidity[b]				
1 pregnancy	1		1	
>1 Pregnancy	0.82 (0.60-1.13)	0.221	0.90 (0.62-1.31)	0.592
Mode of delivery[c]				
C-section	1		1	
Vaginal birth	0.95 (0.73-1.24)	0.732	1.11 (0.81-1.52)	0.512
Smoking				
Smoker	1		1	
Non-smoker	1.56 (1.21-2.01)	0.001	1.65 (1.22-2.24)	<0.0001
Alcohol				
Drinker	1		1	
Non-drinker	0.63 (0.48-0.83)	0.001	0.67 (0.48-0.94)	<0.0001
Folic-acid supplement[b]				
No	1		1	
Yes	1.59 (1.24-2.03)	0.000	1.68 (1.25-2.26)	<0.0001
Five a day[b]				
No	1		1	
Yes	1.57 (1.07-2.32)	0.022	2.30 (1.51-3.50)	<0.0001
Fish[b]				
No	1		1	
Yes	1.41 (1.08-1.84)	0.012	1.60 (1.18-2.17)	<0.0001
Anxiety Index	0.99 (0.98-1.00)	0.003	0.99 (0.98-1.00)	<0.0001
Perceived Stress Scale	0.98 (0.97-1.00)	0.084	0.97 (0.95-1.00)	<0.0001
Depression Scale	0.96 (0.94-0.99)	0.003	0.94 (0.95-0.97)	<0.0001
Limiting response	0.94 (0.91-0.96)	0.000	0.86 (0.83-0.89)	<0.0001
All or nothing response	1.02 (1.00-1.04)	0.215	1.02 (0.99-1.05)	0.260

[a]Reference category: low physical activity level; [b]Missing values; [c]Recoded at birth [d]1 denotes reference category [e]BMI category World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2)

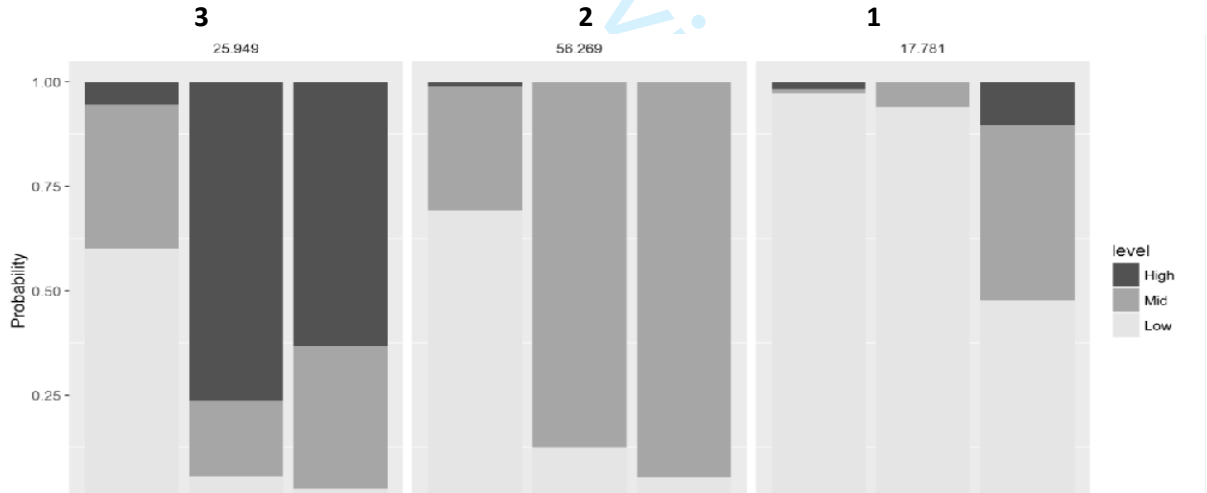
Supplementary file 4: Model fit statistics and three class model definitions

Latent class models were estimated using Mplus version 8.0. The model allowed the two thresholds for each of the 3-level response variables be freely estimated within each specified latent class. Maximum likelihood estimated was employed, using 10k random starts and 1k final stage optimizations. The best observed final stage log likelihood was consistently repeated across random starts. The Mplus code used to estimate the models, as well as additional information on model fit and information criteria and a graphical summary of the three latent classes we focused on, are given below.

a. Model fit statistics



b. Response probability for the three classes



Class 3 High Physical Activity Level: Active group (majority high level moderate exercises and walkers with some mid/high level vigorous exercisers)
Class 2 Moderate Physical Activity Level: Moderately active exercisers (majority mid-level moderate exercisers and walkers)
Class 1 Low Physical Activity Level: Predominantly low exercisers (with some mid/high level walkers)

c. Mplus code

```
Names =
regid vigorous moderate rec_walk;
Missing are . ;
Usevariables =
regid vigorous moderate rec_walk;
Categorical =
      vigorous moderate rec_walk;
Idvariable = regid;
Classes = c(3);
ANALYSIS: Type   = Mixture;
          Starts = 10000 1000;
          processors = 3;
MODEL:
%OVERALL%
%c#1%
[vigorous$1* vigorous$2*];
[moderate$1* moderate$2*];
[rec_walk$1* rec_walk$2*];
%c#2%
[vigorous$1* vigorous$2*];
[moderate$1* moderate$2*];
[rec_walk$1* rec_walk$2*];
%c#3%
[vigorous$1* vigorous$2*];
[moderate$1* moderate$2*];
[rec_walk$1* rec_walk$2*];
```