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Physical activity through generations:

Family linkage data from the HUNT Study

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Abstract

The aim of this study was to investigate familial associations in leisure time physical activity. We used data form the HUNT study, where we included parents form HUNT1 (1984-1986) and their adult offspring form HUNT3 (2006-2008). The family relationship between parents and their offspring was found using their unique 11-digit personal identification number at Statistics Norway. The analysis consisted of 24 649 mother-offspring pairs, 20 965 father-offspring pairs, and we also constructed 17 692 trios including mother, father and offspring. We measured leisure time physical activity in three different perspectives. Logistic regression was used to calculate odds ratio (OR). All analysis were adjusted by possible confounders; parental age, body mass index (BMI), education level, and smoking habits. The results showed that offspring physical activity level was associated with parental physical activity level; offspring of parents who were highly physically active had lower OR of inactivity, than those of parents who were less active or inactive. We also found that offspring of parents who were physically active had a higher OR of being physically active themselves. These associations became stronger the more physically active the parents were. Finally, the results show that physical activity in either parent was associated with a reduced OR, partly irrespective of the other parent physical activity level. In conclusion, with this population-based family study, we found consistent associations between parents and their adult offspring for all three leisure time physical activity measures studied.

Keywords: genetic epidemiology, familial relationship, adult offspring, public health, physical activity.

Contents

1 Introduction

The World Health Organization (WHO) recommends adults to do at least 2.5 hours of moderate-intensity aerobic physical activity per week[1]. Physical activity is a contributor to the health and quality of life for people of all ages[2, 3, 4]. Remaining physically active reduces the risk of cardiovascular disease, metabolic syndrome, type 2 diabetes, obesity and then prolongs life [5, 6, 7, 8, 9, 10, 11]. Still, physical inactivity leads to about 1.9 million deaths worldwide each year[1], and is increasing among adolescents [12, 13]. A Lancet article from 2012 found that the global prevalence of inactivity was 17%[14]. In the U.S., 30% of adolescents failed to meet national recommendations for moderate to vigorous physical activity in 2005 [15], and already in 1998 recognized WHO obesity as a major health epidemic [16]. Increasing obesity and decreasing physical activity is a larger problem in countries with highly developed economies[17]. One might think that countries with highly developed economies bring with it an increased standard of living and more health conscious population. However, the trends observed are that less economically developed countries are more active during the day, when physical activity is inherent in occupation, household, and transportation[17]. Further, in higher developed economic countries, there is a stronger trend using leisure time to be physically active, than in less developed economic countries. Common features among countries of lower and higher developed economies is that male, young, and wealthy groups are more active than others. However, there are disagreements whether it is decreasing physical activity that leads to increasing obesity, or the increasing obesity that brings with it decreased physical activity[17].

There are different required factors for the promotion of physically active lifestyles[18], both environmental, social and personal factors. It is likely that increased digitization may affect the allocation of our free time. For instance, television viewing among adolescents is associated with decreased physical activity and overweight [19]. In addition, one example of policy interventions is Denmark, who has successfully completed a cycling infrastructure. Still, there are disagreements whether policy interventions contribute to physical activity[17]. Research has found that factors as parental overweight and low socio-economic status, and adolescents sedentary behaviour, increases the risk for the adolescents to become overweight or obese[20]. A longitudinal prospective study found that body mass index (BMI) is inherited from the mother[21]. Studies on genetic determinants and physical activity found that there is an association between parents and children, or between twins, when it comes to their level of physical activity [22]. Several diseases are hereditary, in the meaning of a greater probability of the offspring of getting a disease if one or both parents have had it. Different types of cancer, such as colorectal cancer [23] and cardiovascular disease [24] is hereditary. However, a new study about chronic pain associations between adolescent and parents, concluded that shared environment are one of the main factors in the origin of chronic pain[25]. As for physical activity there are studies suggesting that it is the environmental factors that contributes the most to the associations of physical activity through generations [26, 27].

In this study we will look at the familial relationship of physical activity, whether there is an association between parents and their adult offspring in terms of participation and level of physical activity.

2 Methods

2.1 Study population

Nord-Trøndelag County is located in the middle part of Norway with a population of 127 000 in 1984, increasing to 130 000 in 2008. The population structure of Nord-Trøndelag is stable and fairly representative of Norway, except that it has no big city, and mean income and education level is slightly less than the national average. The population studied is almost exclusively Caucasian (around 97% in 2000)[28].

2.2 Data collection

The HUNT study is a Norwegian population-based general health study[29]. Every citizen in the county of Nord-Trøndelag aged 20 years and above were invited to participate in the HUNT study.

Table 1: The different HUNT studies.

The HUNT studies	Conducted year	Invited citizens	Participated citizens (%)
HUNT1	1984 - 1986	86 404	77 212 (89%)
HUNT2	1995 - 1997	93 898	65 237 (70%)
HUNT3	2006 - 2008	93 860	50 807 (54%)

Table 1 show the participation in the different HUNT studies. HUNT1 was conducted in year 1984-86, were 86 404 citizens were invited and 77 212 (89%) attended. In 1995-97 HUNT2 were conducted. The number of invited citizens were 93 898, and 70% (65 237) attended. In HUNT3, 93 860 citizens were invited and 50 807 (54 %) attended. HUNT3 was conducted in year 2006-08. Data were collected from questionnaires, blood and urine samples, and clinical measurements. A more detailed description of procedures and methods can be found at http://www.ntnu.edu/hunt.

Each participant in the HUNT database has their unique 11-digit personal identification number attached. This was used to establish a family relationship at Statistics Norway between parents and their offspring who also had participated. To maintain comparability across the different surveys, we limited our analysis to family units with parental participation in HUNT1 and offspring in HUNT3. Furthermore, parental and offspring had to have complete data on physical activity, in addition to parental age, BMI, education level, and smoking habits.

There were 24 649 mother-offspring pairs and 20 965 father-offspring pairs. In some analyses, we excluded offspring where only one parent participated in the HUNT1, and constructed 17 692 complete trios consisting of mother, father and offspring.

2.3 Ethics

All participants in the three HUNT surveys consented according to Norwegian law and recommendations; in HUNT1 by informed and voluntary participation, in HUNT2 and HUNT3 by signed informed consent. Participants may at any time withdraw from the study and require that their information be deleted. Approvals were obtained from the Regional Committee for Ethics in Medical Research.

2.4 Study variables

2.4.1 Physical activity

We have looked at leisure time physical activity from three different perspectives. The original questionnaires form the HUNT studies about physical activity, can be found in Appendix, Figure 1.

First we constructed a variable reflecting total hours of exercise per week by combining two questions:

> How often do you exercise? (Take an average.) With exercise we mean for example, walking, skiing, swimming, or training/sports.
>
> How long do you exercise each time?

The participants were asked to report the frequency; never, <1 /week, 1 /week, 2-3 /week, or daily. The response options for the number of minutes were; < 15min, 16-30min, 31-60min, or > 60min. By multiplying frequency per week with number of minutes per session, we constructed an estimate of weekly hours of physical activity. The answers of these two questionnaires were recoded into a categorical score and classified into four levels of hours per week; inactive, < 1 h/w, 1-2.4 h/w, or $\geq$ 2.5 h/w. We also used this information to construct two dichotomous variables among offspring; one classifying offspring as inactive or not, the other classifying offspring as highly active (i.e. $\geq$ 2.5 hours) or not. These variables were used as outcome (dependent) variables in the logistic regression model.

Further we constructed a summary score incorporating all three measures of activity. The two questions that were used to calculate the hours per week, in addition to:

> How hard do you exercise? (Take one average.)

The participants were asked to report the intensity of their exercise; taking it easy without breathless and sweat, so hard that I get breathless and sweat, or takes me near exhaustion. Physical activity level were recoded from the answers of these three questionnaires into an index with four levels of a categorical score; inactive, < 1 /week, $\leq$ median, or > median.

Finally we used the question about frequency alone as an categorical variable. Using the existing response options as categories; never, <1 /week, 1 /week, 2-3 /week, or daily.

2.4.2 Other factors

Age was recoded into six intervals; $\leq$ 29 years, 30-39 years, 40-49 years, 50-59 years, 60-69 years, or $\geq$ 70 years. This was included to take into account that the level of physical activity may change throughout life.

Anthropometric factors were measured with participants wearing light clothes without shoes [30]. Height was measured to the nearest centimetre (cm) and weight to the nearest half kilogram (kg). Body Mass Index (BMI) was calculated as body weight in kilograms divided by the squared value of body height in meters (kg/m²). BMI values were recoded into a categorical score and classified into four levels; underweight (< 18.5 kg/m²), normal weight (18.5-24.9 kg/m²), overweight (25.0-29.9 kg/m²), and obese ($\geq$ 30.0 kg/m²).

Education level (only available from HUNT1) was asked if the participants had finished elementary school, secondary school, high school, college or university less than four years, college or university more than four years, or other levels of education. This information was used to classify participants into four categories of education levels; $\leq$ 9 years, 10-12 years, > 12 years, or unknown.

The participants were asked about their smoking history and smoking habits, such as past and present daily smoking, number of cigarettes, time since quitting smoking, etc. This information was used to classify participants into four categories of smoking; never, former, current smoker, or unknown.

2.5 Statistical methods

Characteristics of the study population were analysed using descriptive statics presented as frequencies, means with standard deviations (SD), or percentages. We applied logistic regression to calculate the odds ratio (OR) as a measure of prevalence for offspring physical inactivity as well as high activity, associated with each parent's physical activity, first separately and then combined. In supplementary analysis we made an variable consisting of offspring and each parent who had the same age (± 5 years). Confidence intervals (CI 95%) were calculated for the estimated associations. We also conducted a trend test across categories of physical activity by entering the categories as an ordinal variable in the regression model. All associations were adjusted for confounding by parental age ($\leq$ 29 y, 30-39 y, 40-49 y, 50-59 y, 60-69 y,$\geq$ 70 y), parental BMI (underweight, normal weight, overweight, obese), parental education level ($\leq$ 9 y, 10-12 y, > 12 y, or unknown), and parental smoking habits (never, former, current, unknown).

All statistical analysis was conducted using IBM® SPSS® Statistics V21.0 for Windows (© SPSS Inc., 1989-2012).

3 Results

The study included 24 649 mother-offspring pairs and 20 965 father-offspring pairs. There were 17 692 complete trios consisting of mother, father and offspring.

Table 2: Descriptive statistics of the parent-offspring trios in the Nord-Trøndelag Health study

	Mother	Father	Offspring
Number of participants	11 142	11 145	17692
Age, mean years (SD)	53.1 (15.2)	54.4 (15.0)	48.0 (14.0)
Obesity†, %	15.4	8.6	21.2
>12y education, %	2.7	7.6	N/A
Current smoker, %	27.1	34.1	22.5

N = number of participants, SD = standard deviation, † =BMI $\geq$ 30,0 kg/m², BMI = body mass index, N/A = not available.

Descriptive statistics of the 17 692 parent-offspring trios are shown in Table 2. There were 11 142 mothers, 11 145 fathers and 17 692 offspring, indicating that a substantial proportion of the offspring were siblings. Mean age was 53.1 years in mothers, 54.4 years in fathers, and 48.0 years in offspring. Based on BMI, 15 % of mothers, and 9 % of fathers were classified as obese (BMI $\geq$ 30 kg/m2), whereas a total 21 % of offspring were obese. A total of 3% of the mothers and 8% of the fathers reported education >12 years. The education level among offspring was not available from the HUNT3 data. When it comes to smoking habits; 27 % of mothers, 34 % of fathers, and 23 % of offspring were current smokers.

Table 3 shows the distribution of physical activity level of mother-offspring and father-offspring pairs. There was no obvious pattern in the data, although the chi-square tests suggest a dependency in the distribution in the activity categories between the generations. Overall, a relatively large proportion (> 40%) of parents were classified as inactive, whereas this propor-

Table 3: Percentage parent-offspring trios in categories of physical activity per week

	Offspring hours/week				
	Inactive	0.1 - 0.9 h/w	1 - 2.4 h/w	$\geq$ 2.5 h/w	P-value
Mothers hours/week %:					
Inactive	11.1	8.2	14.7	8.3	
0.1 - 0.9 h/w	5.6	5.2	9.7	5.7	
1 - 2.4 h/w	4.7	4.6	9.2	6.0	
$\geq$ 2.5 h/w	1.3	1.3	2.5	1.8	<0.001*
Fathers hours/week %:					
Inactive	11.1	8.5	14.5	8.3	
0.1 - 0.9 h/w	4.3	4.3	8.0	4.6	
1 - 2.4 h/w	4.3	4.3	8.9	5.9	
$\geq$ 2.5 h/w	2.5	2.3	4.8	3.3	<0.001*

Data presented as total percentage of the mother-offspring pairs, and as total percentage of the father-offspring pairs. *P-value from Chi-square test.

Table 4: Parental - offspring associations: Inactive offspring

Inactive offspring (0.0 hours per week)												
	Mothers - offspring association						Fathers - offspring association					
Parental factor	No	Yes	OR[A]	OR[AB] (95% CI)		P trend	No	Yes	OR[A]	OR[AB] (95% CI)		P trend
Hours/week:												
Inactive	7432	2631	1.00	1.00	(Reference)		6387	2262	1.00	1.00	(Reference)	
0.1 - 0.9 h/w	4921	1326	0.77	0.80	(0.74 - 0.86)		3466	884	0.72	0.75	(0.68 - 0.82)	
1 - 2.4 h/w	4726	1129	0.67	0.70	(0.64 - 0.71)		3904	883	0.63	0.67	(0.60 - 0.73)	
$\geq$ 2.5 h/w	1324	319	0.70	0.73	(0.64 - 0.83)	<0.001	2117	507	0.60	0.70	(0.62 - 0.79)	<0.001
Index:												
Inactive	2600	1040	1.00	1.00	(Reference)		2014	809	1.00	1.00	(Reference)	
< 1 /week	4832	1591	0.78	0.79	(0.71 - 0.87)		4373	1453	0.85	0.88	(0.79 - 0.98)	
$\leq$ median	5058	1359	0.66	0.68	(0.62 - 0.75)		5538	1373	0.63	0.67	(0.60 - 0.74)	
> median	5700	1354	0.54	0.61	(0.55 - 0.67)	<0.001	3851	877	0.57	0.62	(0.55 - 0.69)	<0.001
Frequency:												
Never	2600	1040	1.00	1.00	(Reference)		2014	809	1.00	1.00	(Reference)	
<1 /week	4832	1591	0.78	0.80	(0.72 - 0.88)		4373	1453	0.84	0.88	(0.79 - 0.98)	
1 /week	4887	1306	0.65	0.68	(0.62 - 0.76)		3900	986	0.63	0.68	(0.60 - 0.76)	
2-3 /week	4167	1016	0.60	0.62	(0.56 - 0.69)		3457	718	0.52	0.57	(0.50 - 0.64)	
Daily	2412	614	0.63	0.66	(0.58 - 0.74)	<0.001	2428	664	0.69	0.73	(0.64 - 0.83)	<0.001

N = number of participants, OR = odds ratio, CI = confidence interval, BMI = body mass index.

[A] adjusted for parental age.[B] adjusted for parental BMI, education level and smoking habits.

Table 5: Parental - offspring associations: Highly active offspring

Highly active offspring ($\geq$ 2.5 hours per week)												
	Mothers - offspring association						Fathers - offspring association					
Parental factor	No	Yes	OR[A]	OR[AB] (95% CI)		P trend	No	Yes	OR[A]	OR[AB] (95% CI)		P trend
Hours/week:												
Inactive	8077	1986	1.00	1.00	(Reference)		6954	1695	1.00	1.00	(Reference)	
0.1 - 0.9 h/w	4879	1368	1.12	1.09	(1.01 - 1.19)		3405	945	1.12	1.08	(0.98 - 1.19)	
1 - 2.4 h/w	4419	1436	1.33	1.29	(1.19 - 1.40)		3581	1206	1.41	1.34	(1.23 - 1.47)	
$\geq$ 2.5 h/w	1220	423	1.43	1.39	(1.22 - 1.59)	<0.001	1944	680	1.42	1.37	(1.23 - 1.53)	<0.001
Index:												
Inactive	2976	664	1.00	1.00	(Reference)		2271	522	1.00	1.00	(Reference)	
< 1 /week	5101	1322	1.24	1.23	(1.10 - 1.38)		4683	1143	1.01	0.98	(0.87 - 1.11)	
$\leq$ median	4980	1437	1.31	1.29	(1.16 - 1.44)		5353	1558	1.20	1.14	(1.02 - 1.28)	
> median	5322	1732	1.54	1.49	(1.33 - 1.66)	<0.001	3485	1243	1.47	1.37	(1.21 - 1.54)	<0.001
Frequency:												
Never	2976	664	1.00	1.00	(Reference)		2271	552	1.00	1.00	(Reference)	
<1 /week	5101	1322	1.22	1.22	(1.09 - 1.36)		4683	1143	1.01	0.98	(0.87 - 1.10)	
1 /week	4839	1354	1.27	1.24	(1.11 - 1.39)		3783	1103	1.18	1.13	(1.00 - 1.27)	
2-3 /week	3909	1274	1.50	1.46	(1.30 - 1.63)		3098	1007	1.43	1.33	(1.18 - 1.51)	
Daily	2269	757	1.56	1.52	(1.35 - 1.72)	<0.001	2344	748	1.33	1.27	(1.12 - 1.45)	<0.001

N = number of participants, OR = odds ratio, CI = confidence interval, BMI = body mass index.

[A] adjusted for parental age.[B] adjusted for parental BMI, education level and smoking habits.

tion was smaller in offspring (~ 23%). Moreover, the amount fulfilling the guidelines of at least 2.5 hours of daily activity was small, especially in the parental generation.

Table 4 shows parental activity in relation to offspring inactivity. Overall, all measures of parental activity was inversely related to offspring inactivity (all P-trend values, <0.001). If mothers were active $\geq$ 2.5 hours per week, the OR for offspring inactivity was 0.73 (95% CI, 0.64 to 0.83), whereas the OR for the father-offspring association was 0.70 (95% CI, 0.62 to 0.79), compared to if the parent reported to be inactive. Moreover, if mothers and fathers were in the highest category of the summary score of physical activity (i.e. with a score above the median), offspring had ORs of 0.61 (95% CI, 0.55 to 0.67) and 0.62 (95% CI, 0.55 to 0.69), respectively. The same pattern was also observed for frequency of physical activity, with the smallest OR for offspring inactivity among fathers who reported to exercise 2-3 times per week (OR 0.57; 95% CI, 0.50 to 0.64).

Table 5 shows OR for offspring reporting a high activity level (defined as $\geq$ 2.5 hours per week) associated with the same three measure of parental activity as presented above. In accordance with the results for inactivity, all measures of parental physical activity were positively associated with offspring reporting being highly active (all P-trend values, <0.001). When mothers reported being physically active $\geq$ 2.5 hours per week the OR was 1.39 (95% CI, 1.22 to 1.59), whereas the father-offspring association gave an OR of 1.37 (95% CI, 1.23 to 1.53) compared to if parents were inactive. Analyses of the physical activity score gave ORs of 1.49 (95% CI, 1.33 to 1.66) and 1.37 (95% CI, 1.21 to 1.54) if the mother or the father had a score above the median, respectively. Frequency of physical activity gave largely similar associations as the other two measures.

Supplementary analysis when offspring and parents had a comparable age (i.e. ± 5 years difference) was done to consider that physical activity behaviours changes through life and that offspring might be more similar to their parents when they reach the same age. Overall, the associations remained largely similar to the results from the main analyses. When mothers reported $\geq$ 2.5 hours activity per week the OR for offspring inactivity was 0.74 (95% CI, 0.61 to 0.89) whereas the OR for offspring being highly active was 1.45 (95% CI, 1.22 to 1.73). Corresponding father-offspring associations gave ORs of 0.58 (95% CI, 0.47 to 0.72) and 1.64 (95% CI, 1.36 to 1.98) (data not shown).

In another supplementary analysis we adjusted for the other parents level of physical activity. Overall, the mother-offspring associations became somewhat weaker whereas the father-offspring associations remained largely similar as in the main analyses. The OR for inactivity in offspring was 0.90 (95% CI, 0.75 to 1.07) when mothers reported weekly $\geq$ 2.5 hours of activity, whereas the OR was 0.72 (95% CI, 0.63 to 0.83) when fathers reported the same. For highly active offspring ($\geq$ 2.5 hours per week) when parents reported weekly $\geq$ 2.5 hours of activity, the OR was 1.26 in both associations; mothers (95% CI, 1.07 to 1.49) and fathers (95% CI, 1.10 to 1.43) (data not shown).

Table 6 shows the joint association of maternal and paternal physical activity in relation to

Table 6: Association on physical activity in trios*

	Maternal physical activity[AB]			
	Inactive (95% CI)	0.1 - 0.9 h/w (95% CI)	1 - 2.4 h/w (95% CI)	$\geq$ 2.5 h/w (95% CI)
Paternal physical activity[AB]				
Inactive	1.00 (Reference)	0.87 (0.75 - 0.99)	0.77 (0.65 - 0.90)	1.01 (0.74 - 1.38)
0.1 - 0.9 h/w	0.70 (0.59 - 0.83)	0.79 (0.68 - 0.92)	0.61 (0.49 - 0.74)	0.63 (0.40 - 1.01)
1 - 2.4 h/w	0.79 (0.67 - 0.94)	0.67 (0.56 - 0.81)	0.56 (0.48 - 0.66)	0.58 (0.42 - 0.81)
$\geq$ 2.5 h/w	0.67 (0.54 - 0.84)	0.63 (0.48 - 0.81)	0.63 (0.50 - 0.80)	0.70 (0.54 - 0.92)

*Data presented as crude OR. OR = odds ratio, CI = confidence interval, BMI = body mass index.

[A] adjusted for parental age.[B] adjusted for parental BMI, education level and smoking habits.

offspring inactivity (trios). Overall, the OR for offspring inactivity is reduced when either of the parents are inactive. The strongest association was observed when both parents report being physically active 1-2.4 hours per week (OR, 0.56; 95% CI, 0.48 to 0.66), and higher levels of parental activity did not result in a further strengthening of the association with offspring inactivity.

4 Discussion

4.1 Main findings

In this population-based family study in Norway, we found that offspring physical activity level was associated with parental physical activity level. Offspring of parents who were highly physically active had lower OR of inactivity, than those parents who were less active or inactive. These associations became stronger the more physically active the parents were, as shown by a statistically significant dose-response relation between parental level of physical activity and inactive offspring.

We also found that offspring of parents who were physically active had a higher OR of being physically active themselves, than those whose parents were inactive. Overall, the results shows that physical activity in either parent was associated with a reduced OR, partly irrespective of the other parent physical activity level.

4.2 Comparison with existing literature

Previous studies have reported conflicting findings when it comes to leisure time physical activity transmission through generations. One cross-sectional study in Massachusetts was completed with 380 students, 12-16 years of age and their parents[26]. Another cross-sectional study in Portugal included 2,373 Portuguese families[27]. Each family in the Portuguese-study included the mother, father and two children. Both cross-sectional studies showed that it most likely is an association of physical activity through generations, and it is based on the environmental factors[26, 27], but one of the studies mean that it is not a direct association between generations[26]. A longitudinal study done in Norway with 927 thirteen year old pupils and their parents showed no relationship between parents and children physical activity level[31]. The baseline was done in 1990 and with follow-up after one, two, three, five, six and eight years. The data collection was done primarily by mail, where the questionnaires to the parents did not include all the questions that the offspring received. Although one of the questions was identical, there were not the same response alternatives that the offspring got. This poses some challenges for the validity and generalisability of the results.

Several reviews have examined associations between parents and offspring as children physical activity. One review did not indicate an association between the parental physical activity level and offspring level of physical activity[32]. Nor did it reveal any association between children's physical activity and each parent's level of physical activity alone. However, there was an association between adolescence physical activity level compared to each parent's level of physical activity alone[32]. In another review, six of fourteen articles found a moderate positive correlation, seven suggested that there was little or no correlation, and one article found a negative correlation between parents and offspring physical activity [33]. Overall, the reviews concluded that there is conflicting evidence for an association between parent and offspring

level of physically activity[32, 33, 34].

To our knowledge, no previous study has examined the association between parental physical activity level and their adult offspring level of physical activity. A Norwegian study including a total 2,348 adolescents and their parents examined how environmental factors effects adolescent physical activity. They found that more than half of young people remain inactive, and a large proportion of those who are active relapse during adolescence[35]. This trend is supported by a study from the UK on time trends in physical activity and inactivity who included annual sample sizes consistently over 10,000 from 1993 to 2003[36]. One of two factors in the Norwegian study that proved decisive for adolescences physically activity was the parents level of physical activity. A longitudinal, follow-up study also reported that the parents physical activity was decisive of adolescents physically activity, plus that parental encouragement was determining[37]. Other studies showed that parents support and engagement had a positive effect on offspring level of physical activity[12, 34, 38], although parental monitoring did not[38]. A study on pupils in middle schools in the US, reported that environmental interventions intended to increase physical activity in physical activity classes and throughout the school day were effective among boys, but not in girls[39]. A cohort study in Finland about sports participation as 14 years old adolescents, and a follow-up study at the age of 31 years, found out that participation in intensive endurance sports, and track and field as adolescence was associated with a high or very high level of adult physical activity[40]. This suggests that offspring physical activity behaviour is formed before one move away from home, indicating that the parents' level of physical activity is crucial for offspring level of physical activity also when they become adults. Reviews suggests that one of the most important factors among children and adolescence, and how physically active they are, is walk ability and access to facilities[12, 41]. A study from the US show that neighbourhoods adapted for exercise increases residents physical activity[42].

A review of physical activity and genetic determinants summarizes the evidence as somewhat variable, ranging from low to moderately high correlation between parents and children or between twins[22]. Another review found indications that physical activity is not only the result of combined effects of multiple genes, but also the result of how these genes interact with the environment[43]. This is supported by a Brazilian heart study on whether genetic and environmental factors contribute differently. They did not find any correlation between parents and offspring physical activity. However, a correlation was observed between siblings and cousins physical activity in the same generation, thus suggesting environmental factors are crucial[44]. One study showed that children were twice as likely to be in daily physical activity if their mother were physically active and three and a half times more likely to be in daily physical activity if their father were physically active, compared with if the offspring had inactive parents[45]. Furthermore this study also showed a strong relation; when both parents were active, the offspring were six times more likely to be in daily physical activity. The present study shows not as strong association between parental and offspring level of physical activity. This may be explained by the smaller percentage of participants who are in this group ($\geq$ 2.5 h/w),

compared with the total sample in the present study. However it can also be because we have not studied active vs. inactive alone, but parted active into several groups.

4.3 Strengths and limitations

The strengths of this study are several. This study holds a large data set and the study's population-based design covers the entire population over 20 years within a given geographic area [46] and the participation rate is high. Other strengths are the identical questionnaires on physical activity, and clinical examinations who was measured objectively by trained personnel[46], in both parents and offspring. This to avoid biases that are often affiliated with self-reported anthropometric data [47], and this reduces the possibility that chance findings and selection bias affect the results. In addition, a unique opportunity to study trends through generations is present due the participants data are connected to establish a family linkage at Statistics Norway between parents and their biological offspring, using the unique 11-digit personal identification number of Norwegian citizens. Another strength is that the the data were obtained from adult offspring, suggesting that familiar level of risk factors persist even though the offspring most likely do not share a household environment with their parents[48].

The study has some limitations that should be considered when interpreting the results. Data from 6922 non-participants from HUNT3 is studied[49], and the results showed that non-participants had lower socio-economic status, higher mortality, and prevalence of several chronic diseases. This shows that we cannot exclude the possibility that the families who have participated is a healthier sample than non-participants. Furthermore, the information on physical activity was obtained from identical, self-reported questionnaires. In the self-reported questionnaires, we cannot exclude the likelihood that there is misclassification of activity due to individual interpretation and perception of questions and answers, and seasonal variations in physical activity. This might have attenuated the association through generations on the level of physical activity. Still, the questionnaire on physical activity has been classified as a moderately good measurement for high activity, and also been correlated well with measured oxygen consumption. This validity was done with a random sample of only young men [50], which may reduce the ability to generalize to the total sample included in the HUNT studies. Studies also show that the questionnaires are useful for classifying people into different categories of physical activity[51], and the questions were a good long-term predictor of cardiorespiratory fitness[52]. All associations are adjusted for parental factors as possible confounders.

We used WHO's recommendations as the highest level ($\geq$ 2.5 h/w) in the variable referred hours per week [1]. It was only a small proportion who was in this level ($\geq$ 2.5 h/w), which may have affected the analyses.

However, as in all observational studies, residual confounding cannot be ruled out.

Finally, the present study compared parents and their adult offspring. We did not have information on whether the offspring shared environment with none, one or both of their bio-

logical parents, either in adulthood or when growing up. This is why we cannot distinguish between heredity and environment in the present study. It is possible that the association is stronger in offspring who shared environment with their biological parents during childhood[53]. Non-paternity could weaken the association if they reflect genetic effects.

5 Conclusion

This population-based family linkage study found consistent associations between parents and their adult offspring for all three leisure time physical activity measures studied. Offspring of parents who were highly physically active had lower OR of inactivity, than those parents who were less active or inactive. These associations became stronger the more physically active the parents were, as shown by a statistically significant dose-response relation. Finally, the results shows that physical activity in either parent was associated with a reduced OR, partly irrespective of the other parent's physical activity level. The association showed in the present study between parents and adult offspring indicate that this behaviour last throughout adulthood. More research on generational studies, including grandparents, parents, and offspring, and the information whether they have shared environment during childhood, are needed to establish more answers about transgenerational associations of physical activity.

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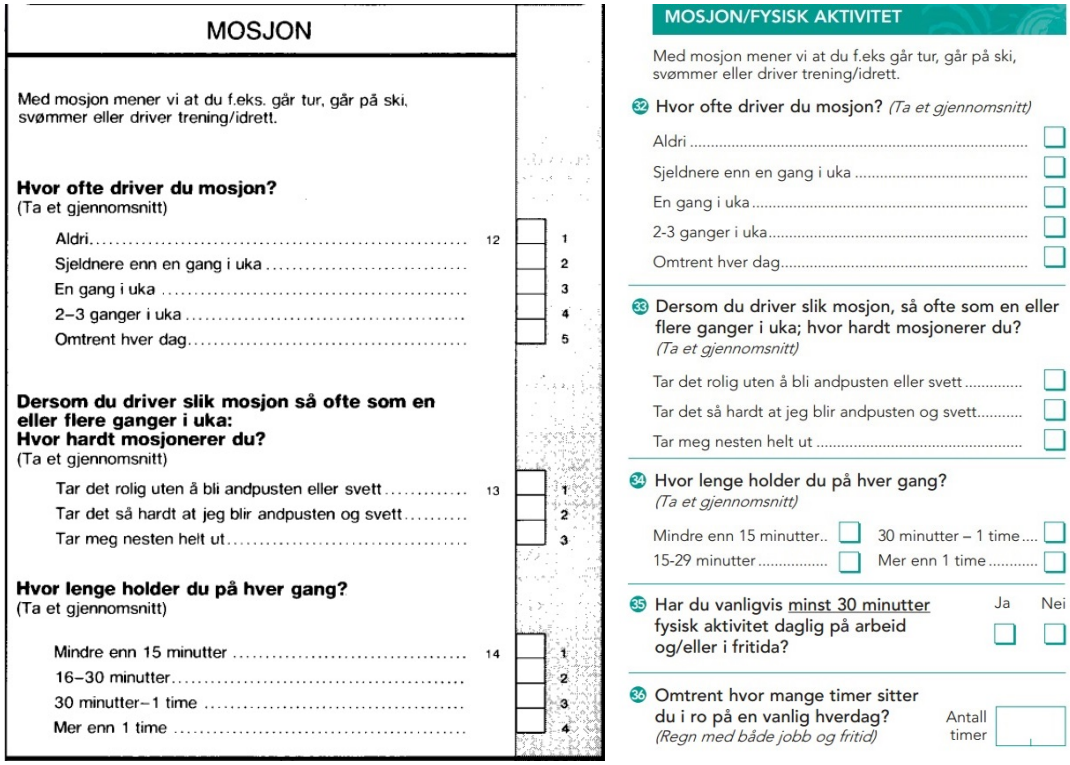
Appendix



MOSJON

Med mosjon mener vi at du f.eks. går tur, går på ski, svømmer eller driver trening/idrett.

Hvor ofte driver du mosjon?
(Ta et gjennomsnitt)

Aldri	12	1
Sjeldnere enn en gang i uka		2
En gang i uka		3
2–3 ganger i uka		4
Omtrent hver dag		5

Dersom du driver slik mosjon så ofte som en eller flere ganger i uka:
Hvor hardt mosjonerer du?
(Ta et gjennomsnitt)

Tar det rolig uten å bli andpusten eller svett	13	1
Tar det så hardt at jeg blir andpusten og svett		2
Tar meg nesten helt ut		3

Hvor lenge holder du på hver gang?
(Ta et gjennomsnitt)

Mindre enn 15 minutter	14	1
16–30 minutter		2
30 minutter–1 time		3
Mer enn 1 time		4

MOSJON/FYSISK AKTIVITET

Med mosjon mener vi at du f.eks går tur, går på ski, svømmer eller driver trening/idrett.

32 Hvor ofte driver du mosjon? *(Ta et gjennomsnitt)*

- Aldri ☐
- Sjeldnere enn en gang i uka ☐
- En gang i uka ☐
- 2-3 ganger i uka ☐
- Omtrent hver dag ☐

33 Dersom du driver slik mosjon, så ofte som en eller flere ganger i uka; hvor hardt mosjonerer du? *(Ta et gjennomsnitt)*

- Tar det rolig uten å bli andpusten eller svett ☐
- Tar det så hardt at jeg blir andpusten og svett ☐
- Tar meg nesten helt ut ☐

34 Hvor lenge holder du på hver gang? *(Ta et gjennomsnitt)*

- Mindre enn 15 minutter ☐
- 15-29 minutter ☐
- 30 minutter – 1 time ☐
- Mer enn 1 time ☐

35 Har du vanligvis minst 30 minutter fysisk aktivitet daglig på arbeid og/eller i fritida? Ja ☐ Nei ☐

36 Omtrent hvor mange timer sitter du i ro på en vanlig hverdag? *(Regn med både jobb og fritid)* Antall timer ☐

Questionnaires about exercise from The HUNT study (original in Norwegian). On the left, questions from HUNT1, and the questions from HUNT3 on the right.

Figure 1: Original questionnaires from The HUNT study.