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A study of the relationship between the general physical fitness of adolescents aged 15-19 years and their parents

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A study of the relationship between the general physical fitness of adolescents aged 15-19 years and their parents

Law, Christopher J

Abstract

The purpose of this study was to determine the degree of familial resemblance in general physical fitness between adolescents and their parents. Data was gathered from a sample of adolescent-parent pairs. Parents with children between the ages of 15-19 years of age were recruited by means of a poster campaign in the Abergele, Colwyn Bay and Llandudno postal areas of Conwy, North Wales. A sample of 32 adolescent-parent pairs was employed in this research. Participants completed the International Physical Activity Questionnaire, and had anthropometric measures taken. The performance of adolescent-parent pairs was then measured for aerobic capacity, static strength, muscular endurance and flexibility. A correlational research design was employed for the project. The level of significance was set at $p<0.01$. All statistical calculations were performed using SPSS (Version 14.0 for Windows). Familial correlation models were fitted directly to the data under the assumption that the family data follow a multivariate normal distribution. The results indicated significant parent - offspring resemblance for weight (0.50), aerobic capacity (0.52), muscular endurance (0.48) and flexibility (0.60) and significant father/son resemblance for weight (0.29), height (0.46) and grip strength (0.39), together with mother/daughter resemblance for weight (0.33) and height (0.48). The results suggest that familial and perhaps genetic, factors are important in explaining the variance in general physical fitness.

Declaration

This work is original and has not been previously submitted in support of a Degree, qualification or other course.

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A study of the relationship between the general physical fitness of adolescents aged 15 – 19 years and their parents.

Chapter 1 - Introduction

The debate over "nature versus nurture" has engaged researchers for centuries. The first attempt to formulate the question scientifically was that of Galton (1869) who argued for the paramount importance of inheritance over environment and experience in influencing an individual's physical and mental capacities. Pioneering work carried out by educationalists in the 1920's and 1930's refuted this view, maintaining that education could overcome the disadvantages of inheritance. The methods derived by these educationalists were first applied to the study of "nature versus nurture" in physical fitness in the early 1970's (Spurway 2006).

Many traits, from behaviour to health outcomes, have a tendency to run in families. Families not only share an environment but also genetic factors. Therefore, most traits are influenced by both genetic and environmental factors to varying degrees. The heritability of a trait is defined by Katzmarzyk, Gledhill, Perusse and Bouchard (2001) “as the proportion of the total trait variance that can be attributed to genetic factors.”

While epidemiologists have traditionally looked for environmental causes for variations in health outcomes and behaviour, geneticists have focused on tracing genetic factors of importance (Frederiksen & Christensen 2002).

Sing and Boerwinkle (1987) observed that the methods used to study the genetic basis of traits, or phenotypes, can be divided into two basic approaches:-

- The "unmeasured genotype" approach is based on statistical analysis of the distribution of traits in individuals and families. This approach is also referred to as the "top-down" approach, since inferences about the influence of genes are made from the trait.
- The "measured genotype" approach uses genetic variation in genetic markers and evaluates the impact of variation at the DNA level on the trait being studied. Since inferences about the role of genes are made from the DNA to the trait, the approach is known as the "bottom-up" approach.

Susser (1985) noted that the first step in the study of the genetic basis of a trait or phenotype is to determine whether or not the trait aggregates in families. The presence of familial aggregation, or familiality, is demonstrated by the higher occurrence of a trait within families compared to the population at large. In the presence of familial aggregation, correlations among family members are expected to be significantly different from zero. To provide evidence for familial aggregation, correlations between family members provide insights about the relative importance of genetic and environmental factors (Plomin, Defries, McClean & McGuffin 2005).

After a particular trait has been shown to aggregate in families, the next step is to quantify the contribution of genetic factors to the familial aggregation.

The genetic analysis of traits is based on partitioning the total trait, or phenotype (V_p), variance into genetic and environmental components as follows:

$$V_p = V_G + V_C + V_E$$

where V_G is the genetic component of the variance and V_C is the (shared) common environmental variance and V_E is the non-shared environmental component of the variance (Bouchard et al. 1997).

The concept of heritability is frequently used when estimating the relative contribution of genetic and environmental sources of variation to a trait. Spurway (2006) defines heritability "as the proportion of total variance in a phenotype attributable to genetic differences". Heritability is usually represented as:

$$h^2 = V_G / V_p$$

and estimates are again typically measured from studies of nuclear families, monozygotic and dizygotic twin pairs and extended family pedigrees.

A heritability close to zero indicates that a genetic variance does not contribute to differences in the trait between individuals, but that the reasons for the trait differences are primarily to be found in environmental exposures (Carlier et al. 1996). Whereas heritability close to 100% indicates that genetic factors are the key determinants of the variance (Silventoinen, Kaprio, Lehelma, 2000). Being a proportion, the heritability is dependent on the effects from environmental factors. Heritability will increase if a trait is influenced both by genetic and environmental factors, and the environment will become more similar for the individuals in the population (Frederiksen & Christensen 2002). Consequently, Bouchard et al. (1997) point out that heritability is a population measure and does not apply to individuals. Estimates of heritability for a given trait are likely to vary among populations, depending on genetic and environmental characteristics of the respective populations.

During the past decades, numerous studies have assessed the relative contribution of genetic factors to traits involved in general physical fitness. General physical fitness refers to those components of fitness that are related to cardiovascular function, muscular strength and endurance and flexibility (American College of Sports Medicine 2006). General physical fitness is related to health status throughout the life span; however there is considerable individual variability in responses to measures designed to improve physical fitness. Consequently, the heritability of general physical fitness characteristics has been widely investigated (Maes, Beunen, Vlietink, Neale, Thomis, Eynde et al, 1996).

Two forms of “top-down” investigation have been used in the study of the genetic contribution to differences in physical performance, fitness and health. Family, and in particular twin studies have provided evidence of a genetic contribution to a number of measures reflecting physical fitness. However, despite the number of studies, a large variability in heritability estimates continues to exist. (Spurway 2006). This variability is partly due to the design and analysis of the studies undertaken.

1.1 Twin studies

The fact that twinning is relatively common and that nationwide twin registers exist in several countries has made twin studies the most widely used tool for estimating the heritability of various trait in humans. Most research, assessing the relative contribution of genetic and environmental factors to general physical fitness, has studied twins. Estimates of genetic influence on fitness derived from these twin studies are almost always higher than those derived from studies in which child-parent relationships are examined (Frederickson & Christensen 2002).

Initial studies of the role of inheritance compared monozygous with dizygous twins. Since the monozygotic twins had identical genetic constitutions (genotypes) it was assumed that any differences in their performance could only be caused by differences in the environments that they had experienced since their conception. By contrast dizygotic twins had genotypes no more alike than those of other siblings, studies therefore regarded the greater variation between the latter as wholly due to the non-identical genomes (Spector 2000).

Early values of heritability in twin studies for performance parameters, such as cardio-vascular function ($\dot{V}O_2max$), arm strength and trunk strength, were up to 93% (Klissouras 1997). These are now considered to be atypically high, probably due partly to chance in relatively small samples and also partly due to systemic errors such as more equal environmental influences on the monozygous twins than the dizygous twins. More recent values are typically in the range of 40 – 80% (Beunen & Thomis 2004), (Huygens et al 2004).

Similarly, a comparison of early heritability values of parameters such as height and weight in twin studies, which are measureable with greater precision than performance parameters, provide estimates in the range 65 - 90% (Falconer 1989). Although it is often assumed that individual differences in weight are largely due to environmental factors such as eating habits and exercise, studies consistently lead to the conclusion that genetics accounts for the majority of the variance for weight (Grilo & Pogue-Geile 1991). Grilo and Pogue-Geile found that twin correlations for weight based on thousands of pairs of twins are 0.80 for monozygotic twins and 0.43 for dizygotic twins. Monozygotic twins reared apart correlate 0.72. Adoptive parents and offspring and adoptive siblings, who share nurture but not nature, do not resemble each other at all for weight. Together, it is argued, the results imply a heritability of about 70%. Similar results are presented for body mass index and for skinfold thickness (Grilo & Pogue-Geile 1991).

However, a more recent tabulation by Frankham, Ballou and Briscoe (2002) finds the mean heritability for size measurement of humans to be 50%.

Table 1 lists a summary of the heritability estimates drawn from twin studies over the past 35 years:-

Table 1 Heritability estimates of physical parameters from twin studies

Parameter	Authors	Date	Type of Study	Heritability
Activity levels	Kaprio	1981	Twin	62%
	Frederiksen	2002	Twin	49%
Height	Falconer	1989	Twin	65-90%
Adult weight	Falconer	1989	Twin	70%
Height/weight	Frankham et al	2002	Twin	50%
Aerobic performance	Klissouras	1971	Twin	93%
	Bouchard et al	1986	Twin	47%
	Fagard et al	1991	Twin	80%
	Klissouras et al	1997	Twin	75-87%
Muscular strength	Reed	1991	Twin	65%
	Frederiksen	2002	Twin	52%
Muscular endurance	Huygens et al	2004	Twin	Up to 77%
Flexibility	Kovar	1974	Twin	69%
	Chatterjee	1995	Twin	19%

Adapted from Falconer (1989), Frankham et al (2002), Frederiksen and Christensen (2003) and Spurway and Wackeridge (2006)

Klissouras (1997) notes that crucial to every twin study is the assumption that the variances between monozygotic and dizygotic twins, due to within pair environmental differences, are not significantly different. However, he proceeds to highlight the following complicating factors in twin studies:-

- Most people consider that the post–natal environments of monozygotic twins are more similar than those of dizygotic twins. Nevetheless, it is only the "trait-relevant" environments that matter. Problems arise where monozygotic twins are “passive recipients” of more similar treatments than dizygotic twins. If an environmental similarity is created by the monozygotic twins, as a consequence of genetically determined traits, then it is an expression of their genetic similarity and not a confusing factor. Thus analysis of whether or not the post-natal environment of monozygotic twins in a study has been more similar than that of dizygotic twins is extremely difficult (Spector 2000).

- As monozygotic twins share the same placenta before birth it is rare for them to get exactly equal nourishment in the pre-natal state. The possibility of lasting differences in muscle biology and performance potential cannot therefore be dismissed.

Klissouras cautions that if the monozygotic twins studied have on average had more similar experiences, the heritability estimates computed will be inflated. Spurway (2006) observes that this is likely to be the major reason why estimates from other study designs are usually lower. He concludes, “Appreciating this, many authors now interpret high values of heritability as indicating strong “familial” influence but not an entirely genetic one”.

1.2 Parent-offspring studies

In addition to the older style heritability analysis used in twin studies, path analysis, a more flexible statistical approach, allows a wider range of family members to be compared (Purcell 2000). Path analysis allows information to be derived about the relative roles of inheritance and environment from non-twin relatives. Simplifying assumptions are still needed, but different assumptions can be compared for the strength of their influence on the fit of the model to data. Path analysis usually produces lower heritability estimates than twin studies (Spurway 2006).

The majority of studies of wider family groups all show that indicators of general physical fitness are inherited characteristics, although estimates of heritability vary from measurement to measurement. In addition, estimates of the extent of genetic influence on wider parameters related to physical performance have been tabulated by Maes et al (1996), Klissouras (1997), Thomis et al. (1998) and Huygens et al. (2004). All have similar implications but are expressed in terms of correlation coefficients or ratios instead of heritability estimates (Spurway 2006).

1.2.1 Height and weight

Wilson (1986) notes that parent-child correlations for stature are stable throughout childhood, decline around puberty, and then increase during the latter phases of growth. Furusho (1974) however, cautioned that parent-child correlations must be interpreted in the light of the fact that the correlation decreases as the difference in age between parents and offspring increases. He also points out that when the stature of parents and children is correlated at the same chronological age, variation in coefficients with time is not apparent. Although correlations for stature with parent and offspring at the same chronological age is not easily obtained, a summary of data for parents and offspring over 15 years of age, produced by Bouchard and Lortie (1984), yielded a mean weighted parent-child correlation of 0.49 (6,344 pairs).

Pioneering work by Tanner (1953 and 1962) and Robson (1978) on the regulation of stature and weight through early childhood suggests three generalisations: (1) genes associated with length and weight at birth, appear to be different from those responsible for adult stature and weight (2) there is a set of genes associated with adult stature and weight; and (3) there is another independent set of genes which regulates the rate of growth in stature and weight.

Meyer (1995) also observed that the genetic factors that affect body weight begin to have their effects in early childhood. He found no heritability for birth weight, increasing heritability during the first year of life and stable heritabilities of 60 to 70% thereafter. These studies led Plomin et al. (2000) to conclude that “genetic effects on weight are largely stable after infancy, although there is some evidence of genetic change” and that,” body weight shows high heritabilities, about 70%, and little influence of shared environment”. This conclusion contrasts sharply with data from Grilo and Pogue-Geile (1991) that showed that biological parents and their offspring are almost as similar in weight (correlation of 0.23) as non-adoptive parents and their offspring (correlation of 0.26). The wide divergence in results from research into the genetics of body weight are summed up by Mueller (1995) who observed, “parent-child correlations for body weight are far less consistent than those for stature and suggest a lower heritability”

1.2.2 Activity levels

General similarity of activity levels and patterns in children and their parents is commonly reported but studies of familial aggregation of activity level and sports participation are relatively few. Moore, Lombardi, White, Cambell, Oliveria and Ellison (1991) investigated the level of habitual physical activity in 100 children, 4 to 7 years of age and 99 mothers and 92 fathers. Using a Caltrac accelerometer data was obtained over a year. The study concluded that active fathers were more likely to have active offspring than inactive fathers or mothers, with odds ratios of 3.5 and 2.0 respectively. When both parents were active, the children were 5.8 times more likely to be active as children of two inactive parents. Bouchard (1997) believed that these results are compatible with the notion that genetic and/or cultural factors transmitted across generations may predispose a child to be active or inactive.

Familial resemblance in leisure time energy expenditure was estimated in data from the 1981 Canada Fitness Survey by Perusse, Leblanc and Bouchard (1988). A total of 18,073 individuals living in households across Canada completed a questionnaire on physical activity habits. Detailed information on the frequency, duration and intensity of activities performed on a daily, weekly, monthly and yearly basis was used to estimate average daily energy expenditure (per kilogram of body weight) for each individual. Familial correlation for parents and offspring (n=1,622 pairs) was 0.12, suggesting only a small contribution of genetic factors in the familial aggregation of leisure time energy expenditure.

From the study of Danish twins by Gaist et al. (2000) it was estimated that the contribution of genetic effects to the variation in physical activity levels was 49%, and conversely 51% of the variation was due to environmental effects.

1.2.3 Aerobic capacity

Aerobic performance tests can be either maximal or sub-maximal and both procedures have been used in estimates of genetic effects in performance. Most studies of the genetic effects in aerobic performance are based upon the twin model, with less data available for other types of relatives.

Relatively few studies of aerobic performance in various family members and relatives are available. In the Tecumseh community health study, heart rate response to a step test (20.3cm bench, 24 steps per minute, energy expenditure of about 5 METS) was measured in parents and their offspring (Montoye, Metzner & Keller 1975). There were significant parent-child similarities in the heart rate response to the step test. Using measured or predicted (for older fathers) maximal aerobic power adjusted for age, weight and fatness, the father/son correlation was 0.34 (Montoye & Gayle 1978). The relationship was stronger, 0.65, when only fathers below 40 years of age were considered. Bouchard observed that these results emphasised the differential effect of environmental factors associated with ages of fathers and sons.

Resemblances between different kinds of biological relatives in maximal and sub-maximal aerobic performance are summarised in Table 2. The data is derived primarily from the Quebec Family Study. Sub-maximal and predicted maximal aerobic performances were derived during work on a cycle ergometer (Lortie et al. 1982), (Lesage et al. 1985), (Perusse et al. 1987a) (Perusse et al. 1987b) and (Perusse, Leblanc & Bouchard 1988). Maximal aerobic power ($\dot{V}O_2max$) was measured on a treadmill in several sub-samples (Lesage et al. 1985). Supplementary estimates of sub-maximal power output were derived from a step test in a nationally representative sample of the Canadian population in the Canada Fitness Survey (Perusse 1988).

Table 2 Familial correlations for aerobic performance in relatives by descent

Source: **Test:**	**Lesage** $\dot{V}O_2$**max measured**	**Lortie et al.** $\dot{V}O_2$**max predicted**	**Perusse PWC 150/kg**	**Perusse PWC 150/kg**
Parent-child	0.03	0.17	0.14	0.47
Father-child	-0.10	0.17	0.13	
Mother-child	0.28	0.17	0.16	

Adapted from Bouchard et al. Genetics of Fitness and Physical Performance

Bouchard et al. (1992) noted that sub-maximal power output was characterised by significant familial resemblance. In addition, although less extensive, correlations for predicted and measured maximal aerobic power also indicated significant familial resemblance. However, in the only study that measured $\dot{V}O_2max$ in parents and offspring (Lesage et al. 1985), the parent-child correlation was low and not significantly different from zero. Interestingly, the mother-child correlation was higher than that for the father–child pairs, which may suggest a possible maternal effect for this phenotype. Similar differential parent-child correlations were not evident in predicted and measured maximal aerobic power (Lortie et al. 1982). When factors influencing aerobic performance (e.g. fatness, smoking, habitual physical activity and socio-economic status) were statistically controlled, variation in sub-maximal and maximal aerobic power was about two to three times greater between families than within families (Bouchard et al.1992).

In a study of 483 sedentary subjects from 99 white families participating in the HERITAGE Family study Perusse et al. (2001) indicated significant familial resemblance in predicted aerobic capacity. This pattern of familial correlation is similar to the Quebec Family study and the Canada Fitness Survey (Perusse et al. 1987) cited above. In another study performed with the same population, maximal heritability for aerobic capacity, which included the transmission of both genetic and non-genetic factors, reached 22% (Perusse et al. 1988).

Bouchard et al. (1998) studied the predicted aerobic capacity in the sedentary state in 86 families. They found significant correlation of this phenotype in various parent-offspring relations, but also among the spouses. A heritability estimate of approximately 50% was reported. Lesage et al.

(1985) estimated mother-offspring correlations for aerobic capacity to be higher than father-offspring correlations. By modelling these results it was estimated that the maternal "heritability" was approximately 30%.

Aerobic performances also show significant resemblance between spouses (Table 3). Bouchard attributes such similarity to positive assortative mating for the trait and/or a common lifestyle associated with cohabitation.

Table 3 Spouse correlations for aerobic performance

Source	**Test**	***r***
Montoye and Gayle (1978)	$\dot{V}O_2$max, measured or estimated, adjusted for age, weight, fatness	0.18
Lortie et al. (1982)	$\dot{V}O_2$max, predicted	0.33
Lesage et al.(1985)	$\dot{V}O_2$max, measured	0.22
Maes (1992)	$\dot{V}O_2$max, L/O_2 ml/min/kg	0.42 0.35
Bouchard et al. (1984)	PWC_{150}/kg	0.19
Perusse et al. (1987)	PWC_{150}/kg	0.21
Perusse et al. (1988)	PWC_{150}/kg	0.17

Adapted from Bouchard et al. Genetics of Fitness and Physical Performance

1.2.4 Muscular strength and endurance

Relatively large-scale parent-offspring studies of strength, undertaken in Poland by Wolanski and Kasprzak (1979) are reported only as correlations: parents and offspring 7 to 39 years old from 570 three-generation rural families and parents and offspring 3 to 42 years old from 347 primarily one generation urban families (Szopa 1982). Parent-offspring correlations were variable, ranging from -0.24 to +0.62. Generally a similar pattern of correlations was reported in 1981 by Kovar for grip and back strength between Czech parents and their 16 to 17 year old sons.

Strength data from the Tecumseh (Michigan) community health study were analysed in a different manner by Montoye et al. (1975). The aggregation of strength: sum of right and left grip, arm strength using both arms simultaneously and an index based on the two measurements corrected for body size and fatness.

Table 4 Correlations in muscular strength and endurance in relatives by descent

Relatives	Strength (quadriceps isometric)	Endurance (sit-ups)	Strength (grip / weight)	Strength (push-ups)	Endurance (sit-ups)
Parent-child	0.32	0.23	0.20	0.25	0.24
Father-child	0.31	0.22			
Mother-child	0.31	0.25			

Adapted from Perusse et al. 1987, 1988 Canada Fitness Survey and French Canadian families in Quebec City area

Parent-offspring resemblances were significant and there was no age effect. Resemblances between parents and older offspring (16-39years) were similar to those between parents and younger offspring (10-15). However, female offspring tended to resemble their parents more than male offspring. Correlations between parents and their offspring for muscular strength and endurance are summarised in Table 4 above.

Mother-child and father-child correlations for muscular strength did not differ.

Estimates of transmissibility from parents to offspring for grip strength in a sample of Mennonite families was zero, there was however, significant sibling resemblance in grip strength that was almost completely explained by shared environmental effects (Devor & Crawford 1984).

Katzmarzyk et al. (2001) studied the familial aggregation of a large number of traits (grip strength, number of press ups, number of sit ups, and a sit and reach test) involved in musculoskeletal functioning (strength, endurance and flexibility). When comparing the within-family with the between-family variability, membership of a family accounted for 48%-59% of the variance in these traits. The performance of the spouses in these samples did not correlate significantly in grip strength but did correlate in muscular endurance. Frederiksen and Christensen (2002) believe that this pattern suggests a role for genes in explaining the familial resemblance of the former trait, and that familial non-genetic effects play a role in the latter.

1.2.5 Flexibility

Flexibility data for biological relatives are not extensive. In a Mennonite community study undertaken by Devor and Crawford (1984) correlations for lower-back flexibility in parent-offspring pairs was 0.29. A study by Perusse et al. (1997) of a nationally representative sample of the Canadian population found a correlation of 0.26 for parents and their offspring.

Katzmarzyk et al. (2001) reported estimates of familial correlation of 0.32 for parents to offspring for trunk flexibility. The estimate of the transmissibility from parents to offspring “through both biological and cultural paths” for trunk flexibility was 64%. Therefore, although the data is limited these findings suggest a somewhat greater genetic influence in flexibility than in strength.

1.3 Review summary

From the review set out above it can be seen that there are widely varying conclusions about the extent of genetic influence on weight and height, levels of physical activity and measures of general physical fitness. In his survey of the field over 35 years Spurway (2006) observes that where there are several estimates for the genetic contribution to differences in physical capacity, the divergence between the largest and smallest figures cannot be comfortably ignored. He attributes some of this variation to the different samples of people studied, noting that a heritability estimate is only applicable to the population actually sampled. A further problem Spurway identifies is that of sample size. Several of the “classical” studies were of very small samples. These factors, together with errors of technical origin and the differences between the fundamental assumptions underpinning studies, all contribute to the range of estimates arising from the top-down studies of the contribution of inheritance and environment to differences in physical functioning and physical fitness.

Bouchard, Malina and Perusse (1997) state that for every individual "nature and nurture" are interwoven. Nevertheless, the accurate assessment of the relative contribution of genetic and environmental factors to general physical fitness is critical in designing interventions that improve fitness in an ageing and increasingly obese population. During this review no published studies related to the heritability of the core components of general physical fitness in non-twin relatives have been identified. This research therefore, aims to assess the contribution of inheritance to the core determinants of physical fitness, including body mass for stature, physical activity levels, aerobic capacity, muscular strength and endurance, and flexibility. This will be done by testing the null hypotheses, that there is no parent-offspring resemblance in anthropometric measures, levels of physical activity, or measures of general physical fitness, and that there is no sex difference in parent-offspring resemblance in anthropometric measures, levels of physical activity, or measures of general physical fitness.

Chapter 2 – Method

2.1 Subjects

A review of eighteen leading research papers published over the past three decades, on the subject of the relative roles of environment and inheritance in familial fitness, was undertaken and revealed a mean sample size of 31 pairs of subjects. A heterogeneous sample of 32 adolescent-parent pairs was employed in this research and a correlation study was undertaken to establish the strength of the relationship between the anthropometric, physical activity and general fitness data for the pairings.

The effect of gender was examined by comparing data for the four gender permutations of father-son, mother-son, father-daughter and mother-daughter.

Parents with children between the ages of 15-19 years of age were recruited by means of a poster campaign in the Abergele, Colwyn Bay and Llandudno postal areas of Conwy, North Wales (Appendix 1). Posters were displayed in local shops, libraries, post offices and town and village halls.

Three pairs of respondents declaring one or more negative answers on an "Exercise Readiness Questionnaire" (Appendix 2) were excluded. Random samples of 32 pairs were then selected from respondents with adolescent offspring within the designated age group.

2.2 Definitions and methods of measurement

The following definitions and methods of measurement were used for the parameters examined in this study:-

General physical fitness – is a multi-dimensional concept that has been defined by Caspersen, Powell and Christenson (1985) as a set of attributes that people possess or achieve that relates to the ability to perform physical activity, and is comprised of skill-related and physiologic components (President’s Council on Physical Fitness 2000). Skills related components of physical fitness are mostly associated with sport and motor skills performance and were not examined in the current study. Health related physical fitness is associated with the ability to perform daily activities with vigour and the possession of traits and capacities that are associated with a low risk of premature development of hypokinetic diseases (American College of Sports Medicine (ACSM) 2006). Health related components of fitness include body composition, cardiovascular endurance, muscular strength and endurance and flexibility. All the health related components of general physical fitness were examined in this study.

In addition, as it is widely acknowledged that the increased energy expenditure associated with regular physical activity may contribute to improved general physical fitness, levels of physical activity were also measured. Similarly, as changes in body size during growth, maturation and ageing are strongly correlated with changes in physiological performance measures (Welsman & Armstrong 2000) height and weight were assessed in the current study.

Anthropometric measures – height and weight were measured to the nearest millimetre and 0.1kg respectively using the American College of Sports Medicine (ACSM) (2006) basic principles and guidelines.

Physical activity – is defined as bodily movement that is produced by the contraction of skeletal muscle and that substantially increases energy expenditure (ACSM) (2006). Methods of estimating levels of habitual physical activity include mechanical activity meters, motion sensors, diaries, interviews and standardised questionnaires. The International Physical Activity Questionnaire (IPAQ) was developed and tested for use in adults (age range of 15-69 years) to "enhance the comparability between surveys" of physical activity. IPAQ assesses physical activity undertaken across a comprehensive set of domains including: leisure time physical activities; domestic and gardening activities; work-related physical activity and transport-related physical activity.

The IPAQ long form (Appendix 3) was used in this study measuring subjects reported activity in the "last 7 days" before testing. The long form was chosen as it was believed that asking more detailed questions regarding physical activity within the domains was likely to produce higher estimates than the more generic IPAQ short form (IPAQ 2005). Computation of the total scores for the long form require summation of the duration (in minutes) and frequency (days) for all the types of activities in all domains. However, as with all self-reporting instruments, data from the IPAQ long form is subject to over or under-reporting. Data collected can be reported as a continuous measure (IPAQ 2005). The measure of the volume of activity computed for this study was MET-minutes/week IPAQ.

Aerobic capacity – maximal oxygen uptake ($\dot{V}O_2max$), expressed as $mlsO_2/kg/min.$, is accepted as the criterion measure of cardio respiratory fitness. Maximum oxygen uptake is the product of maximal cardiac output (L $blood.min^{-1}$) and arterial-venous oxygen difference (mL O_2 per L blood). The classical method of measurement of cardio respiratory fitness is by direct measurement of $\dot{V}O_2max$, where the subject undergoes a maximal exercise test and oxygen consumption is measured directly. Whilst this is the gold standard, the equipment is expensive, requires a high level of technical expertise and is unsuitable for individuals for whom exhaustive exercise is not recommended. As a result numerous tests have emerged for the estimation of aerobic capacity (Sykes 2005). Commonly used modes for exercise testing include field tests, treadmill tests, cycle ergometry tests and step tests. The Chester Step Test was used in this study. This is a sub-maximal, aerobic capacity test that is easy to standardise and safely controlled.

Muscular strength – refers to the external force (expressed in kilograms) that can be generated by a specific muscle or muscle group. Strength can be assessed either statically or dynamically. Static or isometric strength can be measured using a variety of devices, including cable tensionometers and handgrip dynamometer (ACSM) (2006). While measures of static strength are specific to both the muscle group and joint angle involved in testing, the safety and convenience offered by the handgrip dynamometer led to its use in the present study.

Muscular endurance – is the ability of a muscle group to execute repeated contractions over a period of time sufficient to cause muscular fatigue (ACSM). Simple field tests such as a curl-up test (Graves, Pollock & Bryant 2001) or the maximum number of press-ups that can be performed without rest may be used to evaluate the endurance of the abdominal muscle groups and upper body muscles, respectively. The curl-up test was chosen for this study as it was considered to be the most suitable test for both sexes. Results were expressed in the number of curl ups completed in one minute, up to a maximum of 25.

Flexibility – is defined as the ability to move a joint through its complete range of motion. Flexibility is joint specific; therefore no single flexibility test can be used to evaluate total body flexibility. The sit-and–reach test was regarded as the best measure of hamstring flexibility (Jackson & Baker 1986). The relative importance of hamstring flexibility to activities of daily living and sports performance requires the use of the sit-and-reach for health related fitness testing (ACSM) (2006). It was consequently used in the current study. Results were recorded in centimetres (cms).

2.3 Age and gender variability

Body size - Changes in body size during growth, maturation and ageing are strongly correlated with changes in physiological performance measures (Welsman & Armstrong 2000) and therefore have a dual significance in the current study. Sex differences in body weight and stature are minor during childhood but are more marked in later adolescence. There is a sex difference in the timing of the adolescent growth spurt, which occurs, on average, about two years later in boys than in girls (Malina & Bouchard 1991). Adult stature is attained in late adolescence, but some individuals continue to grow in stature into their mid-20s (Roche & Davila 1972). Body weight continues to increase gradually from the late adolescence into adulthood. Beginning in the late 30's, stature tends to decline, on average, and the decline increases with advancing years, in both sexes (Bouchard et al. 1997).

Activity levels – Estimated levels of physical activity generally increase from about the age of six years into early adolescence and then decline. The decline in habitual physical activity is more apparent in later adolescence. Males are on average more active than females but also experience a greater decline in physical activity in late adolescence (Malina 1995). Among adults, physical activity on average declines with age. Studies by Stephens and Caspersen (1994) show that there is a 10 to 20% reduction in the fraction of the adult population between the ages of 20 and 40 years that is moderately or vigorously active. Activity levels also vary between the sexes; on average, males are more active than females, and the sex difference is greater for high intensity activities than for activities of low and moderate intensity (Merritt & Caspersen 1992).

Aerobic capacity – shows similar age trends and sex differences during childhood and adolescence. Both sexes show clearly defined adolescent spurts in aerobic capacity, with performance increases to the mid-teens in females and into the mid-20s in males. During adulthood, relative aerobic performance declines with age in both sexes (Bouchard & Malina 1983).

Muscular strength and endurance – performance in muscular strength and endurance improve on average during childhood and adolescence, with boys generally performing better than girls. Both sexes show adolescent growth spurts (Beunen & Malina 1988). Research by Spirduso (1995) into the effects of ageing shows that the strength and muscular endurance performance of males continue to improve until the mid-or late 20s, while that of females is more variable. In both sexes, performances in strength and muscular endurance tasks tend to decline with advancing years, beginning in the 30s.

Flexibilty – lower-back flexibility (sit-and-reach) decreases, on average during childhood into adolescence and then increases. In both males and females, flexibility tends to decline from the mid 20s (Beunen & Malina 1988).

The above review of age and gender variability shows a generally consistent pattern of maturation and decline with years for both sexes. Notwithstanding the absolute differences in relative functioning between the sexes, this consistency is reflected across the performance measures. This consistency is further ensured in the current study by the narrow age range (15 – 19 years of age) and attendant mean physiological maturity of the adolescent subjects. In view of these factors values were not adjusted for the effects of age, sex or body mass.

2.4 Design

The research design employed in this project was that of a correlational study. The main purpose of the study was to establish the strength of the relationship between the general physical fitness of adolescents aged 15 – 19 years of age and their parents. By measuring and then correlating baseline anthropometric measurements and physical activity levels, together with the components of general physical fitness for both groups, the aim was to identify significant variables, thereby focusing further investigations.

The acknowledged weakness of the study design was the absence of concluding causality and the inter-relationship between many variables (Williams & Wragg 2006).

This project was approved by the Health Sciences Research Ethics Committee of the Faculty of Applied Sciences at the University of Chester.

The main ethical issues inherent in the study related to the researcher's responsibility for the participants. All participants were given a clear explanation of the nature of the study (Appendix 4) and informed consent was given by all participants (Appendix 5). The researcher endeavoured to ensure that no physical or psychological harm came to any participant during the study and that confidentiality of personal data was maintained (O'Leary 2007).

The identity of participants was only known to the researcher and the participants' family. The researcher allocated personal identification numbers to participating subjects and no record was kept of participants' names, addresses or other contact details after completion of individual participants' testing.

All data has been securely stored with access to raw data restricted to the researcher and his academic supervisor.

2.5 Procedures

Selected pairs were asked to complete the "Long Last 7 Days Self-Administered Format" International Physical Activity Questionnaire (IPAQ) prior to their fitness tests being carried out. Feedback from this self-reporting assisted in measuring and assessing confounding factors such as physical activity levels.

Participants were tested at the Village Hall, Betws yn Rhos, Near Abergele, Conwy, North Wales. All testing was carried out by the researcher in August 2008.

The following anthropometric measurements were taken for each participant:-

Weight - (Seca 761 scale) - The participant's weight was measured without shoes and with minimal clothing.

Height - (Seca Leicester portable height measure) - The participant's height was measured without shoes, heels together with heels, buttocks, back and head touching the horizontal mast of the portable height measure. The participant's spine and neck was voluntarily extended and the head was horizontal and looking straight ahead when measured height was recorded.

General physical fitness testing was then carried out:-

Aerobic capacity - (Chester Step Test (CST) - CST compact disc - 20cm Reebok Step - Polar F6 Heart Rate Monitor - Rating of Perceived Exertion (RPE) Chart) - Having ensured that there were no medical contraindications to performing the test (using the "Exercise Readiness Questionnaire") and that the test environment was suitable, the participant warmed up with some gentle limbering and stretching movements.

The participant's name and age were entered on the appropriate graphical data sheet together with their Maximum Heart Rate (MHR) (220 - Age) and 80% MHR. Two horizontal lines were drawn on the graph to illustrate these values.

The heart rate monitor was fitted by the participant and the watch receiver retained by the researcher. The participant was then informed what they were required to do. The researcher then turned on the compact disc (CD) player and asked the participant to listen to the instructions and then to commence stepping at the appropriate time and step rate.

After two minutes of stepping at level 1 the participant's heart rate and perceived exertion was checked and recorded on the data sheet. Providing the heart rate was below 80% MHR and RPE below 14, the participant continued stepping at level 2. Heart rate and RPE was again recorded at the end of level 2. The test continued in this manner until either the target heart rate of 80% MHR was reached or the participant reported an RPE of 14.

A visual line of best fit was then drawn through the heart rate points on the data sheet up to the MHR line. A perpendicular line was then drawn down from where the heart rate line crossed the MHR line and the aerobic capacity score in mlsO2/kg/min entered in the appropriate box (Sykes 2005).

Static strength - grip test - (Takei A5401 hand grip dynamometer) - The participant was asked to raise the hand dynamometer above their head and squeeze as hard as possible using the dominant arm, on three occasions. The highest reading (kg) was recorded.

Muscular endurance - curl up test - (mat - metronome) - The participant lay supine on the mat with knees bent at 90 degrees. Arms were placed palms down on the floor by the side of the body. A piece of masking tape was placed level with the finger tips of each hand. A second piece of masking tape was placed 10cm away from the first piece. The metronome was set at 25 beats per minute. The subject then performed controlled curl ups in time with the metronome, the hands sliding forwards so that the second piece of masking tape was touched. The subject performed as many curl ups as possible, in one minute, in time with the metronome, without pausing, up to a maximum of 25. The number completed was counted and recorded.

Flexibility - sit and reach test - (sit and reach box) - Participants sat with their legs out straight and their heels (without shoes) placed flat against the base of the box. Hands were crossed with the arms out-stretched and the participant stretched to a point on the scale as far away as possible without bouncing or using unnecessary force. The backs of knees were kept on the floor when the stretch was made. The best of 3 attempts was recorded.

Abstention from alcohol and tobacco was sought for a period of twelve hours prior to testing. Both parent and adolescent subject were tested within 60 minutes of each other. Testing was carried out at a time to suit participants.

Testing took 60 minutes for each pair of participants and both participants were tested within 60 minutes of one another.

2.6 Statistical analyses

The test results were summarised and tabulated (Appendix 6). Descriptive statistics were reported for each test. The Shapiro-Wilk statistic was used to determine whether or not samples were normally distributed.

The level of significance was set at $p<0.01$. All statistical calculations were performed using SPSS (Version 14.0 for Windows).

For those samples with a value of $p>0.05$ Pearson's Correlation Co-efficient was calculated. Where the value of $p<0.05$ a Spearman's rho correlation test was conducted.

Familial correlation models were fitted directly to the data under the assumption that the family data follows a multivariate normal distribution. The sex specific correlation model was based on four types of relatives: fathers (F), mothers (M), sons (S) and daughters (D), giving rise to four parent-offspring correlations, FS, MS, FD and MD.

The null hypotheses, that there is no parent-offspring resemblance in anthropometric measures, levels of physical activity, or measures of general physical fitness and that no there is no sex difference in parent-offspring resemblance in anthropometric measures, levels of physical activity, or measures of general physical fitness, were tested.

Chapter 3 – Results

3.1 Familial resemblance in parents and offspring

The descriptive characteristics of the sample are presented in Table 5. The mean ages of the fathers and mothers were 48.8 years and 49.1, respectively and the mean ages of the sons and daughters were 17.1 and 18.0 years, respectively.

Table 5 Descriptive statistics for fathers, mothers, sons and daughters

Parameter	***n***	**Mean**	***SD***		***n***	**Mean**	***SD***
		Fathers				**Sons**	
Age (yrs)	16	48.8	3.0		17	17.1	1.9
Weight (kg)	16	88.2	10.8		17	66.5	17.4
Height (m)	16	1.79	0.05		17	1.7	0.09
Activity (METS-mins/week)	16	2298	777		17	1813	632
Aerobic capacity (mlsO_2/kg/min)	16	37.0	6.7		17	45.0	9.9
Static strength (kgs)	16	46.7	3.9		17	42.6	5.8
Trunk strength (*n*)	16	19.0	6.0		17	23.0	2.0
Flexibility (cms)	16	26.0	5.0		17	32.0	5.0
		Mothers				**Daughters**	
Age (yrs)	16	49.1	3.8		15	18.0	1.7
Weight (kg)	16	64.2	8.1		15	51.4	8.6
Height (m)	16	1.6	0.05		15	1.6	0.07
Activity (METS-mins/week)	16	1558	284		15	1605	399
Aerobic capacity (mlsO_2/kg/min)	16	31.0	5.2		15	43.0	8.8
Static strength (kgs)	16	28.4	3.7		15	28.1	2.5
Muscular endurance (*n*)	16	14.0	6.0		15	22.0	4.0
Flexibility (cms)	16	29.0	5.0		15	37.0	4.0

The parents, on average, were heavier than children of the same sex, with fathers on average 32.6% heavier than sons and mothers 24.9% heavier than daughters. As a group, fathers were 5.3% taller than sons, with mothers and daughters having the same average height. Fathers reported the highest mean IPAQ score, 26.8% greater than sons and 47.5% above daughters. Mothers reported the lowest levels of physical activity.

In the Chester step test (assessment of aerobic capacity), the offspring had mean scores greater than their parents. Group norms for aerobic capacity were "average" when categorised by mean age for all but fathers, the latter collectively classified as "good" (Sykes 2005). Fathers had the highest mean grip strength, 9.6% greater than sons, with mothers and daughters recording similar mean scores of 28.4 and 28.1kgs respectively. The children returned markedly greater mean scores for muscular endurance (curl up test) and flexibility (sit and reach test) than parents.

Table 6 Classification of mean results against norms

Parameter	Fathers	Mothers	Sons	Daughters
Body Mass Index[1]	overweight	overweight	normal	normal
Activity[2]	moderate	moderate	moderate	moderate
Aerobic capacity[3]	good	average	average	average
Static strength[1]	normal	normal	normal	normal
Muscular endurance[1]	good	good	good	good
Flexibility[1]	fair	fair	fair	good

[1] American College of Sports Medicine classification and norms
[2] International Physical Activity Questionnaire categories
[3] The Chester Step Test norms for aerobic capacity

To obtain an indicative measure of the body mass classification, activity levels and fitness categorisation by age, of the group tested, the mean values recorded in Table 5 were assessed against the applicable norms and the results are set out above, in Table 6.

The classification in Table 6 shows that the mean body mass index for both sets of parents categorises them as marginally “overweight”, while the offspring groupings fall into the “normal” category. Activity levels are recorded as “average” for the four sub-groups. Only the mean score for the fathers is categorised as “good” against the norms for aerobic capacity by sex and age. Static strength is “normal” for all sub-groups with the mean muscular endurance classified as “good” for all types. The mean “good” flexibility score for daughters was the only flexibility score to rise above a “fair” categorisation.

Table 7 Familial aggregation of anthropometric, physical activity and general physical fitness measures

Parameter	***r***	r^2
Weight (kgs)	0.50**	0.25
Height (m)	- 0.17	0.03
Activity (METS-mins/week)	- 0.13	0.02
Aerobic capacity (mlsO_2/kg/min)	0.52**	0.27
Grip strength (kgs)	- 0.08	0.01
Muscular endurance (*n*)	0.48**	0.23
Flexibility (cms)	0.60**	0.36

**Correlation is significant at the 0.01 level (2-tailed)

Table 7 above, indicates that the dependent variable, which in this case was family membership, accounted for between 1% and 36% of the variance in the parameters measured. Thus, some anthropometric measures and indicators of general physical fitness aggregate significantly within the families of this sample.

The results suggest that the null hypothesis, that there is no parent-offspring resemblance in anthropometric measures, levels of physical activity or measures of general fitness can be rejected for a number of traits, indicating that there is familial resemblance in anthropometric measures and general physical fitness. For weight, aerobic capacity, muscular endurance and flexibility, the pattern of parent-offspring resemblance, in the absence of significantly shared activity levels, suggests the role of inheritance in explaining a portion of the familial resemblance.

3.2 Familial resemblance in parents and offspring by gender

Estimates of the familial correlations by gender are presented in Table 8,

Table 8 Familial correlations by gender for anthropometric, physical activity and general physical fitness measures

Parameter	Father/Son	Mother/Son	Father/Daughter	Mother/Daughter
Pairs (*n*)	8	9	8	7
Weight (kgs)	0.29**	-0.02	0.08	0.33**
Height (m)	0.46**	-0.04	0.02	0.48**
Activity (METS-mins/week)	0.08	-0.19	0.24	-0.14
Aerobic capacity (mlsO_2/kg/min)	0.01	-0.19	0.24	-0.03
Grip strength (kgs)	0.39**	-0.12	0.05	-0.33
Muscular endurance (*n*)	0.09	-0.21	0.19	-0.06
Flexibility (cms)	-0.28	-0.08	0.13	0.24

**Correlation is significant at the 0.01 level (2-tailed)

For anthropometric measures, father/son pairings and mother/daughter pairings reveal significant correlations for both weight and height.

No statistically significant familial correlations were evident in the sample for measures of activity, aerobic capacity or muscular endurance. However, in father/son pairings gender accounted for 8% of the variance in grip strength.

For this limited sample, the results suggest that the null hypothesis, that there is no sex difference in parent-offspring resemblance in anthropometric measures or measures of general fitness, can be rejected for a number of traits, indicating that there is a sex related familial resemblance in anthropometric measures and some measures of general physical fitness.

Chapter 4 - Discussion

During the past decades, a number of studies of families, and twins in particular, have assessed the relative contribution of inheritance and environmental factors to traits reflecting various aspects of stature, weight and physical functioning: aerobic capacity, muscular strength, muscular endurance and flexibility. Furthermore, behavioural studies have also explored the genetic contribution to the disposition to levels of physical activity.

In recent years the focus has moved towards the molecular level, with studies of specific genetic factors associated with physical functioning and fitness. However, as Frederiksen and Christensen (2002) noted "although this field will probably contribute with remarkable results in the future, it is still in its infancy", leading Rankinen et al (2001) to conclude that "little has been accomplished to date."

Given the critical importance of prescribing exercise interventions that improve the non-disabled life expectancy in increasingly obese and ageing populations, a greater understanding of the specific inheritance and environmental factors that influence general physical fitness is vital.

Studies of familial influence on physical fitness tend to separate physical fitness into several traits and to investigate these in isolation and often in different populations. While limited in scope and design, this study attempts to investigate familial resemblance in a sample group for all of the major components of general physical fitness.

4.1 Familial resemblance in parents and offspring

4.1.1 Height and weight

A comparison of early heritability values of height and weight in twin studies, provide estimates in the range 65 -90% (Falconer 1989). Meyer (1995) found no heritability for birth weight, increasing heritability during the first year of life and stable heritabilities of 60 to 70% thereafter. Similarly, Plomin et al. (2000) also concluded that genetic effects on weight show high heritabilities, of approximately 70%. These conclusions contrasted sharply with data from Grilo and Pogue-Geile (1991) that showed that biological parents and their offspring were almost as similar in weight (correlation of

0.23) as non-adoptive parents and their offspring (correlation of 0.26). The wide divergence in results from research into the genetics of body weight was summed up by Mueller (1995) who observed, "parent-child correlations for body weight are far less consistent than those for stature and suggest a lower heritability"

The present investigation suggests that family membership accounted for 25% of the variance in weight between parent and offspring and therefore falls between the estimates of Meyer and Plomin, and the correlation of 0.23 for parents and their offspring found by Grilo and Pogue-Gielle.

The tabulation by Frankham, Ballou and Briscoe (2002) found the mean heritability for size measurement of humans, predominantly from the study of twins, to be 50%. A summary of data for stature of parents and offspring over 15 years of age, produced by Bouchard and Lortie (1984), yielded a mean weighted parent-child correlation of 0.49 (6,344 pairs), contrasting sharply with a negligible correlation for height between parents and offspring in the current study. Fagard et al. (1991) found that the assortative mating effect (that tall men tended to marry tall women, and conversely) often influenced the genetic variance for height, giving children a substantial tendency to follow their parents' height. The absence of assortative mating in the sample studied could therefore have contributed towards the result shown in the current study.

4.1.2 Activity levels

Familial resemblance in leisure time energy expenditure was estimated in data from the 1981 Canada Fitness Survey by Perusse, Leblanc and Bouchard (1988). A total of 18,073 individuals living in households across Canada completed a questionnaire on physical activity habits. Detailed information on the frequency, duration and intensity of activities performed on a daily, weekly, monthly and yearly basis was used to estimate average daily energy expenditure (per kilogram of body weight) for each individual. Familial correlation for parents and offspring (n=1,622 pairs) was 0.12, suggesting only a small contribution of genetic factors in the familial aggregation of leisure time energy expenditure.

In a study of Danish twins reported by Gaist et al (2000), the participants provided data on physical activity levels to test the hypothesis that genetic factors contributed to the disposition to physical activity. From the study it was estimated that the contribution of genetic effects to the variation in physical activity levels was 49%, and conversely 51% of the variation was due to environmental effects. After allowing for the fact that twin studies generally provide higher estimates of heritability than family studies (Frederickson and Christensen 2002), the pattern of parent-offspring resemblance, estimated in the current study to be 2%, appears to be at the very lower end of the range.

Physical activity can be assessed using subjective (questionnaires, diaries) or objective (motion sensors, heart rate monitors) methods (Welk 2002). While the long, self administered International Physical Activity Questionnaire

(IPAQ) used in this research has acceptable validity when assessing levels and patterns of physical activity in healthy adults (Hagstomer, Pekka & Sjostrom 2006) interpretation and recall errors can give rise to inaccuracies. The completion of the IPAQ by subjects immediately prior to their fitness tests being carried out could also have contributed to over or under-reporting.

In addition, the adolescent decline in habitual physical activity is more apparent in the "late adolescent" offspring studied in this research (Franks et al 2005). This is due in part to the social demands of adolescence and the accompanying career choices in the transition from high school to work or college.

4.1.3 Aerobic performance

Most studies of the genetic effects in aerobic performance are based upon the twin model, with less data available for parents and their offspring. Relatively few studies of aerobic performance in various family members and relatives are available. Earlier studies based on small samples of twins by Klissouras (1971) and Klissouras, Pirnay and Petit (1973) reported heritability estimates for aerobic capacity of 75 to 93%. Similar parent-child correlations were not evident in predicted aerobic capacity measured by Lortie (1982), who estimated parent-child, father-child and mother-child groupings to have consistent aerobic capacity correlations of 0.17. Nevertheless, work by Bouchard et al. (1998), that predicted aerobic capacity in the sedentary state in 86 families, found significant correlation of this trait in parent-offspring relations, reporting heritability estimate of approximately 50%.

While the estimated correlation of 0.52 for aerobic capacity produced by the current study is considerably above that produced by Lortie (1982), it falls short of the heritability estimate resulting from Bouchard et al. (1998).

The correlation divergence with the Lortie (1982) study is believed to be related to sample size. Lortie's data was drawn from the French Canadian families in the Quebec City area, with a sample size of 1,610 members from 375 families, compared with 64 members from 32 families in the present study. The prevalence of assortative mating in the sample studied could also have contributed towards the results reported.

The present investigation suggests that family membership accounts for 27% of the variance in aerobic capacity measured using the Chester Step Test. As group means for aerobic capacity were categorised by mean age as "average", with the mean aerobic capacity of fathers classified "good", the group studied could not reasonably be classified as sedentary and would therefore not be expected to exhibit a similar estimate of heritability to that noted by Bouchard for a sedentary sample group.

4.1.4 Muscular strength and endurance

Several studies have investigated familial resemblance in muscular strength and endurance by using both family and twin-study design. An analysis of

10 year old twins by Maes, Beunenen, Vleietnik et al. (1993) estimated that 72% of grip strength and 65% of muscular endurance are attributable to inheritance. Nevertheless, as previously noted, twin studies generally produce higher estimates of heritability than family studies. In contrast, estimates of genetic heritability from the Quebec Family Study for parents and offspring were 30% for muscular strength and 21% for muscular endurance (Perusse, Lortie, Leblanc et al. 1987).

Devor and Crawford (1984) reported zero transmissibility for dominant hand grip strength in a sample of Mennonite families. There was however, significant sibling resemblance in hand grip that was almost completely explained by shared environmental effects.

A study of 502 nuclear families by Katzmarzyk et al. (2001) studied the familial aggregation of a large number of traits associated with musculoskeletal functioning (strength, endurance and flexibility). When comparing the within-family with the between-family variability, membership of a family accounted for 48%-59% of the variance in these traits. The performance of the spouses in these families did not correlate significantly in strength and flexibility but did correlate in muscular endurance. Although the study design suffers from difficulties in separating common environmental contributions from genetic effects, Frederiksen and Christensen (2002) believe that it suggests a role for genes in explaining the familial resemblance in strength and flexibility, and that environmental factors play a role in muscular endurance.

Estimates of transmissibility from parents to offspring for grip strength and muscular endurance in the current study are 1% and 23% respectively. While this pattern suggests a role for inheritance in explaining the familial resemblance of the later trait, the negligible transmissibility for grip strength is difficult to explain, as it goes against the uniformly high estimates of heritability in other studies (Maes, Beunenen, Vleietnik et al. 1993) and (Perusse, Lortie, Leblanc et al. 1987). Nevertheless, the results do mirror the zero estimate of transmiisibility obtained by Devor and Crawford (1984) in the study of Kansas Mennonites. Indeed, in the present study there was a significant father/son resemblance in grip strength, which may suggests that inheritance is responsible for explaining a portion of the familial resemblance in grip strength.

4.1.5 Flexibility

As previously noted, flexibility data for biological relatives is not extensive. In the Mennonite community study undertaken by Devor and Crawford (1984) the correlation for lower-back flexibility in parent-offspring pairs was 0.29. A study by Perusse et al. (1997) of a nationally representative sample of the Canadian population found a correlation of 0.26 for parents and their offspring. Katzmarzyk et al. (2001) estimated the maximal heritability of lower back flexibility to be 64%.

Flexibility of the lower back and upper thighs, as measured by the sit and reach test, is commonly regarded as a component of general physical fitness, however, Bouchard and Shepherd (1994) note that flexibility is a joint specific characteristic and it is related more to joint morphology than to general physical fitness.

The relatively high familial correlations of 36% for sit and reach flexibility obtained in this study could therefore be partially explained by the influence of genes on the structure of the hip joint. Although the data is limited, the findings may suggest somewhat more genetic influence in flexibility than in the other parameters measured.

4.2 Familial resemblance in parents and offspring by gender

4.2.1 Height and weight

For anthropometric measures, father/son pairings and mother/daughter pairings in this study reveal significant familial correlations by gender for both weight and height. Father/son correlations for weight and height are reported as 0.29 and 0.46 respectively, with mother/daughter correlations of 0.33 and 0.48 respectively.

In a study of readily measured characteristics, in a selection of species, Frankham, Ballou and Briscoe (2002) estimated the mean heritability for weight measurements of humans to be 50%. The authors also point out that extreme values, even greater than 100% or less than 0% can arise due to sampling variation in small experiments. Given that the sample sizes in the current study were only $n=8$ and $n=7$ for the significant father/son, mother/daughter pairings, the respective familial correlations must be viewed with caution.

Moreover, in addition to the small sample size, research by Furusho (1974) also showed that parent-child correlations for height, increase during the later phase of growth, and decrease as the difference in age between the parents and offspring increases. The restricted age profile of the adolescents tested in this study could therefore compound any extreme values arising from the limited sample size.

4.2.2 Activity levels

Estimates of familial aggregation of habitual physical activity and total daily energy expenditure are relatively few. When available, studies of the genetic heritability of these traits tend to be in the low range (Bouchard et al. 1997).

The study, cited above, by Perusse, Leblanc and Bouchard (1988), using data from the Canada Fitness survey, reported a familial correlation for parents and offspring (*n* = 1,622 pairs) of 0.12, suggesting that there was only a small contribution from inheritance in the familial aggregation of energy expenditure.

No significant familial correlations by gender groups were evident in the study sample for the measure of physical activity reported by participants on the International Physical Activity Questionnaire (IPAQ). Feedback from this self-reporting was also used to assist in assessing confounding factors such as significantly low or significantly high physical activity levels in participating groups. The latter assessment revealed mean activity levels between 1558 and 2298 METS-mins/week and therefore would all be categorised as "moderate" under the Guidelines for Data Processing and Analysis of the International Questionnaire (2005).

The study reported correlations of 0.08 and 0.24 for father/son and father/daughter pairings, not radically divergent from the correlation of 0.12 for parents and offspring reported by Perusse et al. (1988). As previously noted, a potentially confounding factor in the measurement of offspring physical activity levels in the current study is that reporting relates to the high summer period. Malina (1995) points out that many surveys of activity levels in children and youth often overlook seasonal variation, which can be significant. The adolescent decline occurs primarily in the summer, which for most adolescents is probably related to summer employment.

4.2.3 Aerobic performance

Estimated correlations between parents and offspring by parent gender in maximal and sub-maximal aerobic performance range from: 0.03 to 0.47 parent-children; -0.10 to 0.17 father-children; 0.16 to 0.28 mother-children. This data is derived primarily from the Quebec Family Study and the Canada Fitness survey (Lortie et al. 1982), (Lesage et al. 1985), (Perusse et al. 1987a), (Perusse et al 1987b) and (Perusse, Leblanc & Bouchard 1988). In a review of these studies Bouchard et al. (1997) noted that sub-maximal power output was characterised by significant familial resemblance. In addition, correlations for predicted and measured maximal aerobic power also indicated significant familial resemblance. However, in the only study that measured $\dot{V}O_2max$ in parents and offspring (Lesage et al. 1985), the parent-child correlation was low and not significantly different from zero. Interestingly, the mother-child correlation was higher than that for the father–child pairs, which Bouchard et al. (1997) suggested may indicate a possible maternal effect for this trait.

In a more recent study of 483 sedentary subjects, from 99 white families, participating in the HERITAGE Family study Perusse et al. (2001) indicated significant familial resemblance in predicted aerobic capacity. Maximum likelihood estimates of familial correlations from the Perusse et al. (2001) study are compared with results from the current study in Table 9.

Table 9 Familial correlations by gender for aerobic capacity

Parameter	Perusse et al.	Current study
Pairs (*n*)	134	7-9
father/son (*n*= 134)	0.12	0.01
mother/son (*n*= 134)	0.29	-0.19
father/daughter (*n*=150)	0.12	0.24
mother/daughter (*n*=150)	0.29	-0.03

Adapted from Perussse et al. (2001) HERITAGE Family study

While the current study shows a higher familial correlation for the father/daughter gender sub-group than the Perusse et al. (2001) study, estimates of transmissibility for the other gender pairings are well below those recorded by Perusse et al. (2001).

Given that the sample sizes in the current study were only *n=7-9* for the gender pairings, compared with *n*= 134 in the HERITAGE Family study, the resulting familial correlations must be viewed with caution. In addition to the divergence in sample sizes, the mean ages of the offspring tested by Perusse et al. (2001) were 25.4 $\pm$ 6.1 for sons and 25 $\pm$ 6.4 for daughters, compared with 17.1 $\pm$ 1.9 and 18.0 $\pm$ 1.7 respectively, in the current study. The greater physiological maturity of the former groups would be expected to contribute towards a closer correlation between parent and offspring. Furthermore, Perusse et al. (2001) point out that stringent control was exercised over the initial levels of physical activity of the subjects in their study probably contributing “to a reduction of the phenotypic variables and thus to an increase inheritability”.

Finally, the maternal correlation for aerobic capacity, estimated by Lesage et al. (1985) as 0.28, is not evident in the current study. Table 9 shows no significant correlation for mother/son or mother/daughter pairings. While the Lesage et al. (1985) result could suggest a genetic influence expressed through genes solely of maternal descent, effects from exclusive maternal environmental influences cannot be ruled out (Frederiksen & Christensen 2002).

4.2.4 Muscular strength and endurance

The study by Katzmarzyk et al. (2001) found significant familial resemblance by gender group, for measures of muscular strength and endurance, in the Canadian population. Table 10 summarises the researchers' findings and compares them with the present study.

Table 10 Familial ***c***orrelations by gender for grip strength and muscular endurance

Parameter	Katzmarzyk et al.		Current study	
Pairs (*n*)	200-228		7-9	
	Grip Strength -	Muscular Endurance	Grip Strength -	Muscular Endurance
fathers/sons	0.24	0.37	0.39	0.09
mothers/sons	0.24	0.17	-0.12	-0.21
fathers/daughters	0.24	0.37	0.05	0.19
mothers/daughters	0.24	0.17	-0.33	-0.06

Adapted from Katzmarzyk et al. (2001)

With the exception of the father/son pairings, the current study failed to match the uniformly consistent findings of Katzmarzyk et al. (2001) in respect of familial correlations, by gender, in grip strength. In a study of growth, maturation and physical activity Malina and Bouchard (1991) noted that performance in strength tasks improves during childhood and that boys perform better than girls on tasks requiring strength. Boys also show adolescent growth spurts in strength and girls do not. They also observed that the performances of males continue to improve until the mid-or late 20's, while those of females are more variable. In both sexes, performance in strength tasks tends to decline with advancing years beginning in the 30s.

These observations may contribute to a greater understanding of the apparent anomalies between the results of the Katzmazyk et al. (2001) research and the current study. Two factors could be compounding the inherent weakness in the current study arising from the very small sample size.

Firstly, the significant correlation in grip strength between fathers and sons in the current study could arise from the fact that the sons in this study are closer to their physical peak (mean age 17.1 years), than their counterparts in the Katzmarzyk et al. study (mean age 12.4 years).

Secondly, the mean age of the parents in the Katzmarzyk et al. (2001) study was 37.2 years, and the mean age of the offspring was 12.2 years. By comparison the mean age of the parents in the current study was 48.9 years, and the mean age of the offspring was 17.6 years. Consequently, with a relatively lower age differential in the Katzmarzyk et al. (2001) study (25.9 years), compared with an age differential of 31.4 years in the current study, a closer relationship in performance would be expected from the former population.

Correlations between different kinds of relatives, from studies by Perusse et al. (1987/8) for muscular endurance, are summarised in Table 11, overleaf. The highest correlations are obtained for monozygotic twins. However, the presence of significant correlations in non-genetically related individuals suggests that environmental factors and lifestyle shared by family members living within the same household can contribute to the observed familial resemblance. Mother-child and father-child correlations for muscular endurance only differ marginally.

Table 11 Correlations in muscular endurance in relatives

Relatives	Endurance – Curl ups[1]	Endurance – Curl ups[2]
Parent - child	0.23	0.24
Father – child	0.22	
Mother- child	0.25	
Siblings	0.37	0.34
Dizygotic twins	0.19	
Monozygotic twins	0.76	
Uncle/aunt – nephew/niece	-0.07	0.54
First- degree cousins	0.00	
Unrelated siblings	0.03	
Foster parents – adopted child	0.15	

[1]Perusse et al. (1987) French Canadian Families in Quebec City area.

[2]Perusse et al (1988) Canada Fitness Survey

The studies by Perusse et al. (1987/8) from the Canada Fitness Survey, and that from Katzmarzyk et al. (2001) (Table 10), therefore, provide consistent evidence that muscular endurance aggregates within families.

The present study does not reveal similarly statistically significant correlations between gender groups, with the correlation of 0.19 for the father/daughter pairing the only estimate that suggests that there may be familial resemblance for measures of muscular endurance determined by a curl up test. However, given that the sample sizes in the current study was only n=8 for the father/daughter pairings, the respective familial correlations must be treated prudently. A further confounding factor in the divergence of results between the current study and its comparators may be the relatively high level of performance of subjects in the former, resulting in the mean muscular endurance classified as “good” for all sub-groups in the study.

4.2.5 Flexibility

Bouchard et al. (1997) observed that although the data for parent-offspring flexibility was limited, findings suggested somewhat more genetic influence in flexibility than in strength. Katzmarzyk et al. (2001) also concluded that the relatively high estimates of heritability for sit and reach flexibility obtained in their study could partially be explained by the influence of genes on the morphology of the hip joint.

No statistically significant correlations for trunk flexibility between gender pairings resulted from the current study. Nevertheless, father/daughter and mother/daughter pairings recorded estimates of familial correlation of 0.13 and 0.24 respectively.

4.3 Conclusion

Evidence gathered over the past two decades from a number of twin and family studies suggest that genetic factors account for a moderate to substantial proportion of the phenotypic variability of physical activity and general physical fitness (Frederiksen & Christensen 2002).

The tabulation by Frankham, Ballou and Briscoe (2002) found the mean heritability for size measurement of humans, predominantly from the study of twins, to be 50%. From the study of Gaist et al.(2000) it was estimated that the contribution of genetic effects to the variation in physical activity levels was 49%, and conversely 51% of the variation was due to environmental effects.

Work by Bouchard et al. (1998) that predicted aerobic capacity in the sedentary state in 86 families, found significant correlation of this trait in parent-offspring relations, reporting heritability estimate of approximately 50%. Katzmarzyk et al. (2001) studied the familial aggregation of a large number of traits associated with musculoskeletal functioning (strength, endurance and flexibility). When comparing the within-family with the between-family variability, membership of a family accounted for 48%-59% of the variance in these traits.

However, despite the number of studies a large variability in heritability estimates continues to exist. This variability is partly due to the design and analysis of the studies undertaken (Spurway 2006).

Bouchard, Malina and Perusse (1997) noted that for every individual “nature and nurture” are interwoven. Nevertheless, they acknowledge that the accurate assessment of the relative contribution of genetic and environmental factors to general physical fitness is key in designing interventions that improve fitness in an ageing and increasingly obese population. No published studies have been identified related to the inheritance of the complete range of components of general physical fitness in parent and offspring. This research therefore, aimed to assess the contribution of inheritance to the components of general physical fitness in adolescents and their parents. The acknowledged weakness of the study design was the absence of concluding causality and the inter-relationship between many variables (Williams & Wragg 2006).

Nevertheless, the study found significant familial resemblance for anthropometric measures and measures of general physical fitness, in a heterogeneous sample of the population of North West Wales. The results suggest that the null hypothesis, that there is no parent-offspring resemblance in anthropometric measures, levels of physical activity or measures of general fitness, can be rejected for a number of traits, indicating that there is familial resemblance in anthropometric measures and general physical fitness. For weight, aerobic capacity, muscular endurance and flexibility, the pattern of parent-offspring resemblance, in the absence of significantly shared activity levels, suggests the role of inheritance in explaining a portion of the familial resemblance.

In addition, from a limited sample, estimates suggest that the null hypothesis, that there is no sex difference in parent-offspring resemblance in anthropometric measures, levels of physical activity or measures of general fitness can be rejected for a number of traits. The study indicates that there is sex related familial resemblance in father/son and mother/daughter weight and height, together with father/son grip strength.

Recent physical activity recommendations encourage general fitness developing activities as a component of habitual physical activity. Taken together, the results set out above and those recommendations, suggest that lifestyle factors such as physical activity are important in maintaining fitness levels over time, but they must be viewed against the background of genetic susceptibility.

The bulk of the evidence suggests that regular physical activity has favourable consequences on general physical fitness. However, such a conclusion is based on average effects observed in groups of men and women. These influences documented at the level of the group may not fully apply to each member of the group. There are considerable individual differences in the response to regular physical activity, even when all the members of the exercising group are exposed to the same volume of physical activity at the same relative intensity (Lortie et al. 1984).

This study showed that general physical fitness is the culmination of many interacting factors, including genetic constitution. Given genetic individuality, an equal state of general physical fitness is unlikely to be achieved for all individuals even under similar environmental and lifestyle conditions. Allowing for such individuality, it is unsurprising that a minority of adults remain relatively physically fit in spite of a sedentary life style.

Genetic individuality is important in the present context because it has an impact on general physical fitness and health. There are inherited differences in the levels of habitual physical activities and in most components of general physical fitness. There is also considerable evidence that genetic variation accounts for most of the individual differences in the response of general physical fitness components to regular exercise. There are not only individual responses to regular physical activity, but there are also some members of the population who do not respond at all (Perusse et al. 2000).

Understanding the value of a physically active lifestyle requires the recognition that physical activity cannot be viewed in isolation. Differences in the level of physical activity are often imposed on individuals by lifestyle components and by the physical and social environments.

Although this study has shown evidence for familial resemblance in anthropometric measures and measures of the components of general physical fitness, in a sample of the local population, these analyses should be replicated with larger sample sizes in other populations to demonstrate the robustness of the results (Spurway 2006).

More generally speaking, the findings of significant familial inheritance across a range of studies indicates the need for molecular genetic studies aimed at identifying specific genes that are related to changes in general physical fitness. Additionally, there is a need for more refined analyses of the environmental characteristics that may influence the observed familial inheritance (Frederiksen & Christensen 2002).

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University of Chester

Research Subjects Wanted

You are invited to take part in a research study of the general physical fitness of adolescents aged 15-19 years and their parents.

The study will be the basis for an MSc dissertation to be presented at the University of Chester.

Participants will meet the researcher by appointment at the Betws yn Rhos Village Hall. You will be asked to complete the International Physical Activity Questionnaire and your weight and height will be measured.

You will then be asked to complete a series of light to moderately strenuous tests of general physical fitness:-

- Aerobic capacity
- Muscular strength
- Muscular endurance
- Flexibility

Testing is anticipated to take 60 minutes for each participant. All information collected will be kept strictly confidential and individuals who participate will not be identified in any report or publication.

If you have a child aged 15-19 years and would like to take part in this study please contact:-

Chris Law by Email @.chester.ac.uk

Exercise Readiness Questionnaire (ERQ)

Name			Date
DOB	Age	Home Phone	Work Phone

Regular exercise is associated with many health benefits. Increasing physical activity is safe for most people. However, some individuals should check with a physician before they become more physically active. Completion of this questionnaire is a first step when planning to increase the amount of physical activity in your life. Please read each question carefully and answer every question honestly:

Yes	No	1) Has a physician ever diagnosed you with a heart condition **and** indicated you should restrict your physical activity?
Yes	No	2) When you perform physical activity, do you feel pain in your chest?
Yes	No	3) When you were not engaging in physical activity, have you experienced chest pain in the past month?
Yes	No	4) Do you ever faint or get dizzy and lose your balance?
Yes	No	5) Do you have an injury or orthopedic condition (such as a back, hip, or knee problem) that may worsen due to a change in your physical activity?
Yes	No	6) Do you have high blood pressure or a heart condition in which a physician is currently prescribing a medication?
Yes	No	7) Are you pregnant?
Yes	No	8) Do you have insulin dependent diabetes?
Yes	No	9) Are you 69 years of age or older **and** not used to being very active?
Yes	No	10) Do you know of any other reason you should not exercise or increase your physical activity?

If you answered yes to any of the above questions, talk with your doctor **before** you become more physically active. Tell your doctor your plan to exercise and to which questions you answer yes. If you honestly answered no to all questions you can be reasonably certain you can safely increase your level of physical activity **gradually**.

If your health changes so you then answer yes to any of the above questions, seek guidance from a physician.

Participant signature	Date

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (October 2002)

LONG LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

Background on IPAQ
The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ
Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation
Translation from English is encouraged to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Further Developments of IPAQ
International collaboration on IPAQ is on-going and an ***International Physical Activity Prevalence Study*** is in progress. For further information see the IPAQ website.

More Information
More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective.* Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

Appendix 3

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

☐ Yes

☐ No → ***Skip to PART 2: TRANSPORTATION***

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

_____ **days per week**

☐ No vigorous job-related physical activity → ***Skip to question 4***

3. How much time did you usually spend on one of those days doing **vigorous** physical activities as part of your work?

_____ **hours per day**
_____ **minutes per day**

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work**? Please do not include walking.

_____ **days per week**

☐ No moderate job-related physical activity → ***Skip to question 6***

5. How much time did you usually spend on one of those days doing **moderate** physical activities as part of your work?

_____ **hours per day**
_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.

_____ **days per week**

☐ No job-related walking → ***Skip to PART 2: TRANSPORTATION***

7. How much time did you usually spend on one of those days **walking** as part of your work?

_____ **hours per day**
_____ **minutes per day**

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?

_____ **days per week**

☐ No traveling in a motor vehicle → ***Skip to question 10***

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?

_____ **hours per day**
_____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No bicycling from place to place → ***Skip to question 12***

11. How much time did you usually spend on one of those days to **bicycle** from place to place?

_____ **hours per day**
_____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No walking from place to place → ***Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

13. How much time did you usually spend on one of those days **walking** from place to place?

_____ **hours per day**
_____ **minutes per day**

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the **last 7 days** in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shoveling snow, or digging **in the garden or yard**?

_____ **days per week**

☐ No vigorous activity in garden or yard → ***Skip to question 16***

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

_____ **days per week**

☐ No moderate activity in garden or yard → ***Skip to question 18***

17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

_____ **days per week**

☐ No moderate activity inside home → ***Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY***

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

_____ **hours per day**
_____ **minutes per day**

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?

_____ **days per week**

☐ No walking in leisure time → ***Skip to question 22***

21. How much time did you usually spend on one of those days **walking** in your leisure time?

_____ **hours per day**
_____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?

_____ **days per week**

☐ No vigorous activity in leisure time → ***Skip to question 24***

23. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?

_____ **hours per day**
_____ **minutes per day**

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?

_____ **days per week**

☐ No moderate activity in leisure time → ***Skip to PART 5: TIME SPENT SITTING***

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?
_____ **hours per day**
_____ **minutes per day**

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

_____ **hours per day**
_____ **minutes per day**

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?

_____ **hours per day**
_____ **minutes per day**

This is the end of the questionnaire, thank you for participating.

University of Chester

Participant information sheet

"A study of the relationship between the general physical fitness of adolescents aged 15-19 years and their parents."

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following sheet carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or you want more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?

Understanding the effects of lifestyle and family characteristics on general physical fitness is important in improving fitness.

The aim of this study is to look at the effects of lifestyle and inheritance on general physical fitness in families. A written report will be produced at the end of the project. The research will also be the basis for an MSc dissertation to be presented at the University of Chester.

Why have I been chosen?

You have been chosen because you are between 15-19 years of age/have a child between 15-19 years of age.

Do I have to take part?

It is up to you to decide whether or not to take part. If you decide to take part you will be given this sheet to keep and be asked to sign a consent form and to complete an exercise readiness form. If you decide to take part you are still free to withdraw at any time without giving a reason.

What will happen to me if I take part?

If you decide to take part, you will be given this sheet to keep and asked to sign the consent form and to complete an exercise readiness form. This will give your consent to the following:-

- Before testing you will be asked not to drink alcohol or smoke tobacco for a period of twelve hours.
- I will meet you at an agreed time at the Betws yn Rhos Village Hall.
- You will be asked to complete the International Physical Activity form and I will weigh you and measure your height.
- General physical fitness testing will then be carried out:-

  Chester step test – this test requires you to step on and off a low step at a rate set by a music beat. Every two minutes your heart rate will be checked using a heart rate monitor and recorded. The stepping rate will then be increased slightly. The test carries on in this way until you reach 80% of your maximum heart rate. At this point you will feel that you are working hard. Your aerobic fitness rating will then be worked out.

  Static strength – will be measured using a hand grip test. You will be asked to raise the hand grip tester above your head and squeeze as hard as possible using your strongest hand. This will be repeated three times and your highest reading will be recorded.

  Trunk strength – will be measured using a one minute curl up test. You will be asked to lie on a mat with your knees bent at 90 degrees and your arms down on the floor by the side of your body. A piece of masking tape will be placed level with the finger tips of each hand. A second piece of masking tape will be placed 10cm away from the first piece. You will then be asked to perform controlled curl ups in time with a metronome, your hands sliding forwards so that the second piece of masking tape is touched. The number of curl ups completed in time with the metronome without pausing up to a maximum of 75 will be counted and recorded.

Flexibility – will be measured using a sit and reach test box. You will be asked to sit on the floor with your legs out straight and your heels (without shoes) placed flat against the base of a box. With hands crossed and your arms outstretched you will be asked to stretch to a point on the box as far away as possible without bouncing. The best of 3 attempts will be recorded.

Testing will take about 60 minutes.

After the tests you will be given feedback, comparing your results for each of the tests with the standard fitness ratings for people of your age and sex.

What are the possible disadvantages and risks of taking part?

You may feel mild physical discomfort, for short periods during some of the tests that you will be taking.

What are the possible benefits of taking part?

It's possible that you would like to know your current level of general physical fitness.

What if something goes wrong?

If you need to complain or have any concerns about the way you have been approached or treated during the course of this study, please contact Professor Sarah Andrew, Dean of the School of Applied and Health Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 01244 513055.

If you are harmed by taking part in these tests, there are no special compensation arrangements. If you are harmed due to someone's negligence (but not otherwise), then you may have grounds for legal action but you may have to pay for this.

Will my taking part in the study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential. Only my supervisor and I will see the information.

What will happen to the results of the research study?

The results will be presented as a dissertation for the degree of MSc. in *Exercise and Nutrition Science* and may be published. Individuals who participate will not be identified in any report or publication.

Who is organising and funding the research?

I will be funding the research. The Centre for Exercise and Nutrition Science at the University of Chester will be involved in organising the study.

Who may I contact for further information?

If you would like more information about the research before you decide whether or not you are willing to take part, please contact:

Chris Law

@chester.ac.uk

Thank you for your interest in this research.

University of Chester

Participant Consent Form

Title of Project: **"A study of the relationship between the general physical fitness of adolescents aged 15-19 years and their parents."**

Name of Researcher: Chris Law

Please initial box

1. I confirm that I have read and understand the information sheet dated .... for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected. ☐

University of Chester

Participant Consent Form (cont'd)

3. I agree to take part in the above study. ☐

4. I consent to my child's participation in this study. ☐

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Name of Participant	**Date**	**Signature**
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Parent	**Date**	**Signature**
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Researcher	**Date**	**Signature**

Appendix 6

Identification	Age	IPAQ	Weight	Height	Step Test	Grip Strength	Curl Up	Flexibility
	years	MET-mins/wk	Kgs	m	mlsO_2/kg/min	kgs	number	cms
1MDM	49	1598	57.2	1.57	42	27.6	25	25
1MDD	15	2062	39.0	1.42	38	24.2	24	40
2FDF	52	3448	73.0	1.78	49	46.5	25	29
2FDD	15	1952	39.9	1.47	40	25.8	21	39
3MSM	52	1148	59.4	1.58	26	25.5	9	15
3MSS	17	1950	66.7	1.75	61	46.5	25	29
4MDM	52	1088	61.2	1.55	30	27.6	10	25
4MDD	19	1093	69.9	1.58	38	30.1	17	28
5FSF	53	3394	73.5	1.80	50	45.4	25	28
5FSS	18	1728	67.6	1.73	59	45.7	25	25
6FDF	52	3252	73.1	1.78	45	44.2	25	34
6FDD	20	1064	68.0	1.60	32	29.9	18	32
7MDM	54	1283	66.7	1.57	24	31.2	7	29
7MDD	21	1068	53.9	1.63	30	27.1	11	33
8MSM	53	1338	68.0	1.55	30	32.4	8	25
8MSS	18	1218	60.3	1.68	41	47.6	24	30
9FDF	49	3225	92.9	1.76	44	51.2	16	28
9FDD	20	1110	53.1	1.55	34	26.3	24	33
10MSM	52	1383	67.1	1.58	27	31.7	10	29
10MSS	17	1250	62.1	1.73	48	49.4	23	31
11FSF	43	1727	83.0	1.76	35	49.8	17	28
11FSS	15	2992	48.5	1.58	57	36.9	21	34
12MSM	47	1433	83.0	1.63	27	24.1	10	29
12MSS	19	1325	83.9	1.83	37	26.9	20	29
13MSM	46	1373	81.6	1.60	25	23.5	16	28
13MSS	15	1494	44.9	1.63	37	43.8	25	34
14FSF	49	1078	102.9	1.78	29	40.2	8	16
14FSS	20	1298	83.1	1.86	35	36.9	19	31
15FSF	50	1128	101.6	1.81	27	42.2	9	19
15FSS	15	1249	46.7	1.66	31	38.6	17	29
16MSM	49	1838	60.3	1.73	34	27.5	19	25
16MSS	16	2064	63.9	1.68	49	48.2	23	39
17MSM	50	1999	58.5	1.68	38	26.2	20	27
17MSS	15	1933	69.9	1.83	48	44.8	23	40
18FSF	50	1943	76.2	1.78	35	49.8	22	27
18FSS	17	1825	65.8	1.71	58	43.2	25	34
19FSF	51	2002	77.1	1.83	33	45.6	20	28
19FSS	16	2578	68.0	1.86	47	36.9	24	36
20MSM	48	1598	63.9	1.60	29	24.2	10	31
20MSS	16	2837	47.6	1.63	40	41.4	24	40
21FSF	52	2062	92.5	1.91	35	47.8	25	26
21FSS	15	2734	49.9	1.63	47	42.8	25	38
22MDM	41	1892	64.9	1.60	34	33.6	22	37
22MDD	19	1678	54.4	1.58	55	34.8	25	41
23MDM	42	1952	63.5	1.60	37	36.4	21	35
23MDD	17	2061	49.9	1.66	57	29.8	23	39
24FDF	45	2488	103.4	1.76	37	52.6	24	27
24FDD	19	1700	54.0	1.63	54	28.7	25	39

Appendix 6

25FDF	46	2554	93.9	1.73	33	49.9	21	24
25FDD	18	2063	46.7	1.66	44	29.0	25	39
26MSM	49	1554	56.3	1.60	28	26.9	9	33
26MSS	21	1172	102.1	1.81	37	47.9	23	24
27MDM	48	1638	54.4	1.58	30	27.0	11	31
27MDD	18	1603	45.4	1.60	37	27.5	25	37
28FSF	47	1938	88.9	1.78	33	44.8	22	23
28FSS	20	1172	99.8	1.81	29	47.0	25	25
29FDF	46	1950	90.7	1.76	37	40.8	23	28
29FDD	17	1208	47.2	1.58	36	25.5	25	38
30MDM	53	1928	61.7	1.63	35	28.6	19	34
30MDD	17	1730	51.3	1.63	44	28.9	24	39
31FDF	50	1598	95.7	1.88	32	44.2	19	15
31FDD	18	2060	50.4	1.63	44	27.1	20	40
32FDF	45	2983	93.4	1.81	36	51.9	12	29
32FDD	17	1628	47.6	1.58	54	27.0	25	40