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Physical activity, physical fitness, blood pressure, and fibrinogen in the Northern Ireland health and activity survey

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Abstract

Study objective – **To investigate the relationship between physical activity, physical fitness, blood pressure, and fibrinogen.**

Design – **This was a cross sectional population study using a two stage probability sample.**

Setting – **Northern Ireland.**

Participants – **A sample of 1600 subjects aged 16–74 years from the population of Northern Ireland.**

Main outcome measures – **Physical activity profile from computer assisted interview using the Allied Dunbar national fitness survey scales. Physical fitness using estimation of VO_2 max by extrapolation from submaximal oxygen uptake while walking on a motor driven treadmill. Systolic and diastolic blood pressure measured with a Hawksley random zero sphygmomanometer. Measurement of fibrinogen using the Clauss method.**

Main results – **There were significant relationships between both current and past activity and blood pressure. These were of a magnitude that would have been clinically significant, but for the fact that, with the exception of the relationship between habitual activity and diastolic pressure ($p = 0.03$) and past activity and systolic pressure ($p = 0.03$) in men, they were not sustained after adjustment for the effect of age using analysis of variance. After adjustment for other potentially confounding factors using multiple regression, there was an inverse relationship between systolic blood pressure and past activity in men, so that those with a lifetime of participation compared with a lifetime of inactivity had a lower systolic blood pressure of 6 mmHg ($p < 0.05$). There was a highly significant ($p < 0.001$) inverse association between both systolic and diastolic blood pressure and physical fitness (VO_2 max) which was not sustained after adjustment for possible confounding factors. There were relationships between fibrinogen and highest recorded activity ($p < 0.001$), habitual activity ($p < 0.01$), and past activity ($p < 0.01$) in men but no significant relationship in women. The relationship between fibrinogen and activity was no longer sustained after adjustment for possible confounding factors. There was a highly significant ($p < 0.001$) inverse relationship with physical fitness using VO_2 max. This relationship was sustained after adjustment for possible confounding factors in both men ($p < 0.05$) and women ($p < 0.001$).**

Conclusions – **There was a relationship between physical activity, physical fitness, and blood pressure but the relationship was greatly influenced by age. A reduction of 6 mmHg in systolic blood pressure associated with past activity is of clinical significance and supports the hypothesis that physical activity is of benefit in reducing cardiovascular risk. There was a lower level of fibrinogen in those who were most active but this relationship was not significant after adjustment for possible confounding factors. There was also a lower level of fibrinogen those who were most fit (VO_2 max) and this relationship persisted even after adjustment for possible confounding factors.**

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There is considerable evidence supporting the beneficial effect of physical activity and physical fitness on cardiovascular mortality and the effect on risk factors, such as hypertension and plasma fibrinogen, may be one possible mechanism. Epidemiological studies have shown a reduced risk of developing hypertension in physically active persons[1 2] and a meta-analysis of 25 longitudinal studies[3] confirmed the benefits of aerobic exercise in lowering raised systolic and diastolic blood pressures. There is an inverse relationship between vigorous sports participation and hypertension[4] and the relationship between physical activity and blood pressure has been shown to be independent of age, body mass index (BMI), and fasting plasma insulin levels.[5] Blair *et al*[6] found that those with low levels of physical fitness have a relative risk of 1·52 for the development of hypertension when compared with those who are very fit. Intervention, including exercise, was shown to reduce the risk of developing hypertension[7] in a controlled trial of those with high-normal blood pressure at baseline, and has also been shown to lower systolic blood pressure by 11 mmHg and diastolic blood pressure by 8 mmHg in those with mild to moderate hypertension.[3] In general, there has been a linear relationship between activity and blood pressure, but the multiple risk factor intervention trial study[8] and British regional heart study[9] suggested a "J" shaped curve.

There is also interest in the relationship with between physical activity, physical fitness, and fibrinogen. Plasma fibrinogen is a well documented risk factor for cardiovascular disease,[10 11] which is independent of hypertension. Fibrinogen has a role in the clotting mechanism and thus plays an important part in thrombosis. There is evidence from cross sectional[12-16] and longitudinal[17] studies of reduced fibrinogen in those undertaking physical activity.

This study offers the opportunity to explore the relationship between exercise, fitness, and these two important risk factors. Its aim was to examine the relationship between physical activity, physical fitness, blood pressure, and fibrinogen in a cross sectional population survey of physical activity, other lifestyle parameters, and cardiovascular risk factors in Northern Ireland.[18] The particular benefits of this study are the detailed measure of physical activity and the direct measurement of physical fitness using oxygen uptake, and the study is particularly pertinent in a population known for its high level of cardiovascular disease.[19]

Methods

The Northern Ireland health and activity survey (NIHAS), which was designed to yield a representative sample of adults aged 16 years or over in Northern Ireland, employed two stage probability sampling. The first stage was a sample of 1600 addresses taken from the Northern Ireland rating and valuation lists, stratified by region to ensure proportional sampling across the province. The second stage was carried out by the interviewers so that one person was selected in each household using a Kish grid random selection procedure[20] to avoid any chance of self selection by members of the household or bias on the part of the interviewer.

A sample drawn using the Kish grid sampling method is influenced by the numbers in each household, thus the sample was weighted to take account of household size and the appropriate adjustment was made to the method of calculating the standard errors.

The fieldwork, which was completed between February and November 1992, comprised three parts – a computer assisted interview, a physical appraisal, and fasting blood sample determination. The questionnaire was similar (with some modifications relevant to Northern Ireland which did not affect the meaning of the questions; for example to allow for the different measures of alcohol), and the physical appraisal was identical to that used in the Allied Dunbar national fitness survey (ADNFS).[21] The questionnaire was carried out using computer-assisted interviewing and a copy of the questionnaire on disk may be obtained from the Sports Council for Northern Ireland. Those defined as hypertensive included both those whose blood pressure was 160/95 and those who were taking medication for high blood pressure.

Physical activity was classified under three headings:

- The highest level of activity in the four weeks before the interview (none, light, moderate, vigorous).
- The frequency and intensity of bursts of physical activity lasting twenty minutes in the four weeks before the interview which is a more accurate reflection of habitual activity (6 categories: level 0-level 5).
- The years of regular participation in sport and exercise since age 14 years in five categories giving the proportion of life that the person had been active (0, <0·25, 0·25–0·49, 0·50–0·74, 0·75%).

The physical appraisal was performed in a specially designed mobile laboratory at 14 hospital sites throughout the province. Height was measured using a Holtain stadiometer and body weight was measured to the nearest 0·1 kg using a Phillips Electronic scale (HP 5320). Body mass index was used as an index of obesity. Blood pressure was measured with a Hawksley random zero sphygmomanometer. Blood pressure measurements were taken after the height and weight measurements, but before any physical activity. Three readings were taken at one minute intervals after the subject had been sitting resting for 5 minutes. Blood pressure was measured on the left arm using an appropriate sized cuff and diastolic pressure determined using the Korotkoff method.[5] The physical appraisal team (n=4) had regular quality assurance appraisals for technique and interobserver comparability, and the sphygmomanometer was subsequently tested for accuracy.

Aerobic fitness was assessed by oxygen uptake while walking on a treadmill. Maximum oxygen uptake (VO_2 max) was calculated by extrapolation from performance at up to 85% of predicted maximum heart rate. Oxygen uptake, in litres per minute corrected for body weight, and heart rate were recorded on the treadmill three times each minute. A least squares regression line was drawn through each respondent's set of data points. Regression by the least squares method calculates a straight line through each set of data points. Estimation of VO_2 max using this method may be limited by the assumption that each individual has the same maximum heart rate related to age. In addition, the number of data points varied, with some fitter individuals proceeding through the whole 16 minute protocol and others only managing a few minutes before their heart rate rose above 85% of their predicted maximum for age (220 beats per minute – age).

The more demanding protocol began at a treadmill speed of 3 km per hour achieving a mid range speed of 5 km per hour from the 5th minute to the 14th minute. Gradient changes were made every minute from the 6th minute to the 13th minute up to 20 degrees. For fitter subjects, two further speed increments were included to take the subject to target heart rate. The less demanding protocol was at a constant speed of 3 km per hour with an increase in the gradient. These test protocols were identical to those used in the ADNFS.[21]

Table 1 Response to components of Northern Ireland health and activity survey

	No	%
Valid addresses	1456	100
Total interviewed, all ages	1020	70·1
Attended centre for appraisal	567	38·6
Analysable treadmill data	481	33·0
Blood tests	633	43·5

A fasting blood sample (30 ml) was taken on a morning during the week preceding the physical appraisal or not less than two days after the physical appraisal at the respondent's home, place of work, or at the physical appraisal laboratory. Participants had been given verbal instructions and an explanatory letter requesting that they fast from all food and alcohol for 12 hours before the blood test. Samples were centrifuged at 3000 rpm at room temperature, separated, and analysed on the same day. The laboratory is accredited with Clinical Pathology Accreditation UK Ltd. External and internal quality control procedures were used to monitor the quality of the laboratory analyses. Measurement of fibrinogen was by the manual Clauss method[22] (Boehringer Mannheim) using control plasma from Immuno Ltd (Sevenoaks, Kent TN14 5HB, UK).

Data were analysed using *SPSS* on the Microvax 3100 computer at the Department of Epidemiology and Public Health, The Queen's University of Belfast. Analysis of variance was used for comparison of mean blood pressure and mean fibrinogen between activity groups, and two way analysis of variance was used to adjust for age. The association between blood pressure and fibrinogen with activity (or fitness) was examined using multiple regression to adjust for the influence of age, body mass index, alcohol intake (none, 1–9, 10+ units per week), smoking (none, cigars/pipe or <10 cigarettes, 10+ cigarettes per day), education (tertiary, secondary, primary), social class (non-manual, manual), and diet (good, bad; based on consumption of dietary fat and fibre by dietary questionnaire). The survey was approved by the Research Ethical Committee of the Faculty of Medicine, The Queens University of Belfast.

Results

There were 1456 effective addresses – 145 (10%) non-contacts, 285 (20%) refused interview, 1020 achieved interviews (70%), and 6 missing questionnaires (table 1). The weighted sample (M 474: F 546) was comparable to the population distribution of the 1991 Northern Ireland census in relation to sex and age and those who attended the physical appraisal were representative of those who completed the questionnaire in respect of age, height, weight, physical activity, health, and obesity, although they were more likely to be male and non-smokers ($p<0·05$). The figures given in the tables are for the weighted sample.

Mean systolic and diastolic blood pressures are shown in tables 2 and 3. There was an increase in the mean systolic blood pressure with increasing age in both men ($p<0·001$) and in women ($p<0·001$). Overall, 6% of men and women were hypertensive using criteria suggested in 1992 by the European Atherosclerosis Society,[23] and using WHO criteria,[24] the overall proportions of men and women who were hypertensive were 6% and 5% respectively.

The relationships between physical activity and both systolic and diastolic blood pressures were confounded by age, and after adjustment for age only the relationships between habitual activity and diastolic pressure among men ($p=0·03$) and past activity and systolic blood pressure in men were sustained ($p=0·03$).

The relationships between habitual activity, highest recorded activity, past participation, VO_2 max, and blood pressure were examined using multiple regression (table 4). There was a highly significant positive relationship in both men and women between systolic and diastolic blood pressure and age ($p<0·001$) and BMI ($p<0·001$). There was an inverse relationship with VO_2 max ($p<0·001$), but this was not significant after adjustment for possible confounding factors (age, BMI, smoking, alcohol intake, education, social class, and diet).

There was also a relationship between blood pressure and habitual activity in men, with a lower mean systolic blood pressure of 10 mmHg ($p<0·01$) and a lower diastolic blood pressure of 5 mmHg ($p<0·05$) for level 5 compared with level 0. In women there was a lower systolic blood pressure of 9 mmHg ($p<0·05$) and a lower diastolic blood pressure of 5 mmHg ($p<0·01$) between levels 3,4 and level 0; combining levels 4,5 because of small cell sizes resulted in a lower systolic blood pressure of 9 mmHg ($p<0·05$) and diastolic blood pressure of 7 mmHg ($p<0·01$) for levels 4,5 compared with level 0.

Using the highest recorded activity, the systolic and diastolic blood pressures in men were lower by 15 mmHg ($p<0·01$) and 8 mmHg ($p<0·05$) respectively and those in women by 22 mmHg ($p<0·01$) and 11 mmHg ($p<0·01$)

Table 2 Systolic blood pressure (mmHg): men and women

	Age groups (y)						
	All	16–24	25–34	35–44	45–54	55–64	65–74
Men							
No	305	57	69	62	61	27	29
Mean	122	115	120	117	120	133	142
(SD)	(16)	(10)	(13)	(13)	(15)	(19)	(18)
(SEM)	(1·0)	(1·5)	(1·8)	(1·8)	(2·2)	(4·1)	(3·9)
Women							
No	299	59	60	58	56	34	31
Mean	117	104	106	112	124	135	135
(SD)	(20)	(10)	(12)	(14)	(16)	(26)	(22)
(SEM)	(1·3)	(1·4)	(1·8)	(2·1)	(2·5)	(5·0)	(4·5)

Table 3 Diastolic blood pressure (mmHg): men and women

	Age groups (y)						
	All	16–24	25–34	35–44	45–54	55–64	65–74
Men							
No	305	57	69	62	61	27	29
Mean	76	69	75	75	79	80	79
(SD)	(11)	(8)	(10)	(11)	(9)	(15)	(13)
(SEM)	(0·7)	(1·2)	(1·4)	(1·6)	(1·3)	(3·3)	(2·6)
Women							
No	299	59	60	58	56	34	31
Mean	71	66	65	71	78	78	75
(SD)	(11)	(7)	(8)	(8)	(11)	(11)	(10)
(SEM)	(0·7)	(1·0)	(1·2)	(1·2)	(1·7)	(2·1)	(2·0)

Table 4 Multiple regression analysis of systolic and diastolic blood pressure (BP) and their determinants: men and women (coefficient (SEM))

	Age	*BMI*	*VO_2 max*	*VO_2 max adjusted*	*Habitual activity*	*Habitual activity adjusted**	*Highest activity*	*Highest activity adjusted*	*Past participation*	*Past participation adjusted*
Men										
Systolic BP	§ 0·46 (0·06)	§ 1·47 (0·25)	§ −0·41 (0·10)	NS	L0 v L5 ‡ −10·07 (3·26) L0 v L3, 4 ‡ −9·16 (2·97) L0 v L1, 2 † −6·98 (3·17)	NS	None v vigorous ‡ −15·18 (5·77) None v moderate † −11·63 (5·76)	NS	† −6·67 (3·04)	† −5·64 (2·58)
Diastolic BP	§ 0·21 (0·04)	§ 1·11 (0·17)	§ −0·26 (0·07)	NS	L0 v L5 † −4·88 (2·27)	NS	None v vigorous † −8·02 (4·00)	NS	NS	NS
Women										
Systolic BP	§ 0·76 (0·06)	§ 1·23 (0·26)	§ −0·81 (0·13)	NS	L0 v L3, 4 † −8·64 (3·59)	NS	None v vigorous ‡ −21·86 (6·81) None v moderate † −14·78 (6·62)	NS	NS	NS
Diastolic BP	§ 0·30 (0·04)	§ 0·76 (0·13)	§ −0·35 (0·07)	NS	L0 v L3, 4 ‡ −5·28 (1·90) L0 v L1, 2 † −3·82 (1·92)	NS	None v vigorous ‡ −10·59 (3·64)	NS	NS	NS

* Adjusted = adjusted for possible confounding variables; † $p<0·05$; ‡ $p<0·01$; § $p<0·001$.

respectively for those undertaking vigorous activity compared with no activity. These associations were confirmed when the none/light categories were combined due to small cell sizes.

There were also lower mean systolic pressures of 7 mmHg ($p<0·05$) before and 6 mmHg ($p<0·05$) after adjustment for possible confounders between men with a lifetime of participation compared with those who had been inactive all their life.

There was a highly significant increase in fibrinogen with age ($p<0·001$). Fibrinogen was positively associated with BMI ($p<0·001$) in both men and women. There was a relationship between cigarette smoking status in men before ($p = 0·03$) and after ($p = 0·004$) adjustment for age, but there was no relationship in women. In men there was a significantly lower fibrinogen with habitual activity ($p = 0·02$), highest recorded activity ($p<0·001$), and past activity ($p = 0·001$). After adjustment for possible confounding factors, these differences were no longer statistically significant. There was no significant association between fibrinogen and habitual activity, highest recorded activity, or past activity in women (table 5A, B, C).

There was a highly significant ($p<0·001$) inverse association between fibrinogen and fitness as measured by VO_2 max, in both men and women. In men the relationship was such that an increase in VO_2 max of 1 ml/kg/min was associated with a decrement of 0·03 g/l in fibrinogen. This inverse association persisted after adjustment for possible confounders, with an increase of 1 ml/kg/min in VO_2 max suggesting a decrease in fibrinogen of 0·01 g/l ($p<0·05$). In women an increase in VO_2 max of 1 ml/kg/min was associated with a decrement of 0·02 g/l in fibrinogen even after adjustment for possible confounders ($p<0·001$).

Discussion

The age related increase of 27 mmHg in systolic blood pressure among men in Northern Ireland was greater than that found in the corresponding survey in England[25] (the ADNFS; 16 mmHg), while the increase of 31 mmHg among women was comparable (ADNFS; 32 mmHg). The rise in diastolic blood pressure of 10 mmHg from age 16–74 years among men was similar (ADNFS; 8 mmHg) although the rise of 9 mmHg among women was less (ADNFS; 15 mmHg).

While there were reductions in systolic and diastolic blood pressures with increasing physical activity of a magnitude that would be of clinical significance, the association was no longer significant, with the exception of the reduction in systolic blood pressure with past activity in men, when multiple regression was used to adjust for age, BMI, smoking, alcohol intake, education, social class, and diet. This supports the suggestion by Gordon *et al*[2] that much of the relationship between blood pressure and physical activity stems from confounding factors other than physical activity alone. They have pointed out the wide variability in outcome between the studies and suggested that the blood pressure lowering effects may be at least partly dependent on gender, BMI, intensity of exercise, duration of training, and initial blood pressure. A reduction of 6 mmHg in systolic blood pressure with past activity is, however, of clinical significance and supports the suggestion that lifelong habitual physical activity is of benefit in reducing cardiovascular risk.

Table 5 Fibrinogen related to highest recorded activity, to habitual activity and to past participation (proportion of life active): men and women

(A) Fibrinogen related to highest recorded activity

Highest	*None*	*Light*	*Moderate*	*Vigorous*	*p*	*Adjusted for age*
Men						
No	9	18	129	110		
Mean	3·55	3·62	3·14	2·84	<0·001	0·49
(95% CI)	(2·81, 4·29)	(3·16, 4·07)	(2·99, 3·29)	(2·71, 2·97)		
Women						
No	15	16	179	81		
Mean	3·29	3·60	3·34	3·20	0·41	0·70
(95% CI)	(2·64, 3·94)	(3·17, 4·02)	(3·21, 3·48)	(3·01, 3·40)		

(B) Fibrinogen related to habitual activity

Habitual	*Level 0*	*Level 1*	*Level 2*	*Level 3*	*Level 4*	*Level 5*	*p*	*Adjusted for age*
Men								
No	47	47	20	71	24	56		
Mean	3·39	3·14	3·11	3·03	2·78	2·87	0·02	0·87
(95% CI)	(3·12, 3·66)	(2·91, 3·38)	(2·62, 3·61)	(2·84, (3·22)	(2·60, 2·96)	(2·67, 3·08)		
Women								
No	60	50	49	86	25	20		
Mean	3·47	3·26	3·36	3·24	3·00	3·55	0·22	0·44
(95% CI)	(3·22, 3·73)	(2·96, 3·57)	(3·09, 3·63)	(3·09, (3·39)	(2·78, 3·22)	(2·95, 4·15)		

(C) Fibrinogen related to past participation (proportion of life active)

Past	*0*	*<0·25*	*0·25–0·49*	*0·50–0·74*	*0·75+*	*p*	*Adjusted for age*
Men							
No	16	22	35	24	169		
Mean	3·55	3·23	3·29	3·36	2·91	0·001	0·02
(95% CI)	(3·13, 3·97)	(2·91, 3·54)	(2·92, 3·67)	(2·96, 3·76)	(2·80, 3·02)		
Women							
No	33	27	38	35	157		
Mean	3·04	3·32	3·56	3·18	3·34	0·15	0·19
(95% CI)	(2·69, 3·38)	(2·96, 3·68)	(3·23, 3·90)	(2·81, 3·54)	(3·21, 3·47)		

The highly significant inverse association between blood pressure and aerobic fitness, as measured by VO_2 max, was also eliminated after multiple regression was used to adjust for the confounding factors listed above.

There was a relationship between physical activity and fibrinogen, as would have been expected from previous studies, and the margin of difference was both statistically and clinically significant. It is well known that age and smoking habit confound the relationship with fibrinogen, and the relationship between fibrinogen and activity was no longer sustained after adjustment for these confounders. This is in keeping with the work of Lee *et al*,[15] who suggested that the relationship between activity and fibrinogen could largely be explained by smoking, while Connelly *et al*[26] found that those who were vigorously active had lower fibrinogen levels, even after adjustment for age, smoking, alcohol, BMI, and occupation.

Ernst[17] reviewed the relationship between physical activity and fibrinogen levels in longitudinal studies and found evidence of a reduction of about 0·4 g/l with physical activity which is important when we consider that the Northwick Park heart study[27] found that a 0·1 g/l difference in fibrinogen corresponded to a reduction of 15% in the risk of coronary heart disease.

While the relationship with physical activity was no longer sustained after adjustment for age and smoking, the relationship between fibrinogen and physical fitness was sustained. Lakka *et al*[28] suggested that the plasma reducing effect of conditioning physical activity was largely due to increased fitness. Moller and Kristensen[29] suggested that one possible pathway may be physical activity→physical fitness→fibrinogen, but one would have expected that in this model the relationship with physical activity would have been sustained.

Physical activity and physical fitness are not the same, although physical fitness is often wrongly used as a surrogate measure of activity. Physical activity is defined as bodily movement produced by skeletal muscles that results in energy expenditure while physical fitness is a set of physiological attributes that people have or achieve that relate to the ability to perform physical activity. The physical fitness component that has been most frequently studied in relation to health is aerobic power. Physical fitness has a large genetic component, although it is modified by activity, and it is often difficult to unravel the relationships between physical activity which is voluntary and physical fitness which is essentially constitutional. The relationship between fibrinogen, physical activity, and physical fitness may suggest a constitutional effect.

A particular strength of this study is the detailed measure of physical activity. This included physical activity at work and during leisure time in a detailed aggregate based on all activities in a four week period. A further strength was the measure of physical fitness using a direct measure of oxygen uptake, which is the most accurate measure of aerobic fitness. A potential weakness is in the sample size which may not have been sufficient to detect small differences as statistically significant.

Conclusion

There were significant relationships between blood pressure, physical activity, and physical fitness, but with the exception of the relationship between habitual activity and diastolic pressure ($p = 0{\cdot}03$) and past activity and systolic pressure ($p = 0{\cdot}03$) in men, these were not sustained after adjustment for age. When the relationships between blood pressure, physical activity, and physical fitness were examined using multiple regression to adjust for the influence of potential confounding factors, the relationship between systolic blood pressure and past activity was sustained in men, so that those who had a lifetime of participation compared with a lifetime of inactivity had a systolic blood pressure that was 6 mmHg lower ($p<0{\cdot}05$). A reduction of 6 mmHg in systolic blood pressure is of clinical significance and supports the hypothesis that it is the exercise habits of a lifetime, rather than more recent activity, that offer protection against hypertension. There was an inverse association between both systolic and diastolic blood pressure and physical fitness (VO_2 max) which was not sustained after adjustment for possible confounding factors. This suggests that the protective effect of activity may be independent of physical fitness level.

This study also confirms the relationship between fibrinogen and physical activity in men but the relationship was no longer significant after adjustment for possible confounders. There was, however, a relationship between fibrinogen and physical fitness in both men and women before and after adjustment for possible confounding factors. The relationship between physical activity, physical fitness and both these risk factors, blood pressure and fibrinogen, appear to have a different pattern, and the benefits of physical activity and physical fitness may act through different pathways. Longitudinal studies of physical activity and fitness may help further clarify these relationships.

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