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GEOGRAPHICAL VARIATION AND MIGRATION ANALYSIS OF HEIGHT, WEIGHT AND BODY MASS INDEX IN A BRITISH COHORT STUDY

MONIKA KRZYŻANOWSKA* AND C. G. NICHOLAS MASCIE-TAYLOR†

**Department of Anthropology, University of Wrocław, Poland and †Department of Biological Anthropology, University of Cambridge, UK*

Summary. Using a sample of 2090 father and son pairs, the regional variation in height, weight and body mass index (BMI) with intra- and inter-generational migration within Britain was examined. Highly significant regional differences in means were found only for fathers. The overall mean height difference between regions ranged from about 2.7 cm to 3.1 cm, with the tallest fathers being found in the East & South-East region and the shortest in Wales. The variation in mean weight between regions was less significant, with the difference between the heaviest region (West Midlands) and lightest (South-West) being about 3.5 kg. For BMI the highest mean was in the North and Wales and the lowest in the South-West (difference of about 1 kg m^{-2}). Intra-generational migrants were, on average, significantly taller than non-migrants for both fathers (+1.4 cm) and sons (+2 cm), but BMI was only significant in fathers, with migrant fathers, on average, having a lower BMI. There were no significant differences in weight between geographically mobile groups for either fathers or sons. Differentiating between regional in- and out-migration revealed that in the fathers' generation in-migrants were taller, on average, in six of the nine regions. The tallest in-migrants among fathers came into the North region; the tallest out-migrants were from Yorkshire & Humberside and the shortest were from Scotland. The largest positive gain on fathers' height was in the West Midlands region and Scotland, while negative effects were found in the Yorkshire & Humberside, East Midlands and East & South-East regions. For sons in-migrants were taller in all regions except Wales, with the largest differences between in-migrants and non-migrants being in the South-East and South-West. For out-migrants, the tallest sons came from Wales, while the shortest came from the East Midlands region. The North, East Midlands, East & South-East and West Midlands regions were net gainers, while Wales and Scotland were net losers. For BMI among fathers, in-migrants were of lower BMI than non-migrants. For out-migrant fathers, the North-West and South-West regions were the only two regions showing positive values, with the largest

negative values being found in the East Midlands and Yorkshire & Humberside. The net effect of migration indicated that the largest gains were in the East Midlands and Yorkshire & Humberside regions and the largest losses were in Scotland and Wales. The inter-generational migration for BMI showed that in-migrating sons into the North-West and Wales had higher BMI than sedentes, while in-migrants into Yorkshire & Humberside were lower in BMI. In all regions out-migrants had lower BMI than non-migrants. The net effect of migration revealed that six of the nine regions were net gainers, while the Yorkshire & Humberside region was a net loser.

Introduction

The effects of migration have been studied for over 100 years, beginning with the works of Fishberg and Boas (quoted by Lasker & Mascie-Taylor, 1988). Migration impacts on both recipient and donor populations and movement may be selective or random (Mascie-Taylor & Little, 2004). Selective migration promotes or maintains differences between groups or regions (maintains heterogeneity) whereas random migration reduces differences (promotes homogeneity). Mascie-Taylor (1985) showed that migration for IQ is selective while for ABO blood groups it appears to be random.

In general migration studies show that body height is greater in people who change their place of residence (Kobyliansky & Arensburg, 1977; Kim, 1982; Wheeler & Tan, 1983; Bernis, 1984; Steegmann, 1985; Singh & Harrison, 1996). However, some researchers have not found a connection between body height and migration (Lasker, 1954; Malina *et al*., 1982; Zielińska, 1991). Migrants have also been shown to have more advanced sexual maturation and higher body mass index (BMI) than non-migrants (Garnier *et al*., 2003; Nagel *et al*., 2009).

This paper examines regional variation in anthropometric traits and the effects of intra- and inter-generational geographical migration on height, weight and BMI within Britain.

Methods

The sample comprised the fathers and sons who were members of the National Child Development Study (NCDS). The NCDS commenced in 1958 when all children born in England, Wales and Scotland in the week 3–9th March were examined. The children and their families were periodically re-studied in 1965, 1969 and 1974. Thereafter the index child was followed up into adulthood and there were re-studies at 33 and 40 years of age. This paper focuses on the 2090 father–son pairs for whom there were complete data on weight and height (see Krzyżanowska & Mascie-Taylor, 2011, for additional information). The few pairs from ethnic minorities were excluded from the analyses.

In these studies families were placed into one of the nine standard regions comprising North, Yorkshire & Humberside, East Midlands, East & South-East, South-West, West Midlands, North-West, Wales and Scotland (see Fig. 7A). Thirty-three per cent of the fathers came from the East & South-East region and only

Table 1. Percentages of inhabitants in the nine regions

	Fathers		Sons	
Regions	1958	1974	1991	2000
North	8.3	8.3	6.7	7.0
Yorkshire & Humberside	7.8	7.2	7.9	7.5
East Midlands	7.2	7.5	7.5	7.6
East & South-East	33.0	33.2	34.6	33.3
South-West	6.2	7.1	8.8	9.5
West Midlands	10.2	9.7	9.4	9.5
North-West	10.4	10.1	9.2	9.4
Wales	5.2	5.5	5.5	5.4
Scotland	11.7	11.4	10.4	10.8
Total	100	100	100	100

5.2% (in 1958) and 5.5% (in 1974) came from Wales. Most of the sons came from the East and South-East (34.5% in 1991) and, similarly to fathers, only 5.5% (in 1991) and 5.4% (in 2000) came from Wales (Table 1).

The extent of geographical mobility was determined intra-generationally for the fathers (between 1958 and 1974) and for the sons (between 1991 and 2000), as well as inter-generationally between fathers and sons (between 1958 and 2000). Geographical mobility was categorized as none (no change in place of residence), in-migrants (in-migration into another region) and out-migrants (emigration from one region to another). Univariate analysis of variance was the main statistical tool used with Hochberg's or Games-Howell's *post-hoc* tests.

Results

Mean anthropometric traits by regions

Figures 1 and 2 present the mean height of fathers by region on four occasions and that of sons by region on two occasions. Highly significant differences in regional mean heights were found only in fathers (Table 2). The greatest mean height was in the East & South-East region, while the lowest mean was in Wales. The overall mean height difference between regions ranged from about 2.7 cm to 3.1 cm in fathers.

There was much less difference in mean weight between regions (Figs 3 and 4) but much more in BMI (Figs 5 and 6). In fathers the greatest mean weight was generally in the West Midlands, while the lowest was in the South-West (maximum difference about 3.5 kg). For BMI the greatest mean value was in Wales and the North, and the lowest in the South-West (maximum difference about 1 kg m^{-2}). There was no significant regional variation in weight or BMI in the sons' generation (Table 2).

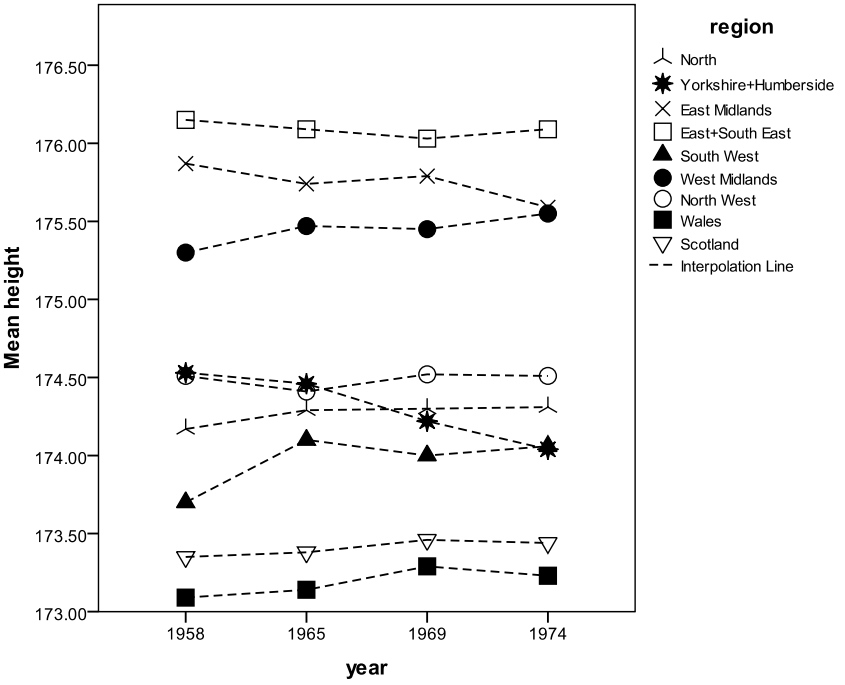

Fig. 1. Fathers' height variation by region.

Intra- and inter-generational migration

Fathers were classified as non-migrants if they remained in the same region between 1958 and 1974, and migrants if they moved to another region over this time period. The same classification was used for sons between 1991 and 2000 and also for father–son migration between 1958 and 2000.

Table 3 presents the results of the analyses for height, weight and BMI between geographically mobile and non-migrant groups. Intra-generational regional migration was 9.3% for fathers and 6.7% for sons, while inter-generational regional migration was 22.2%. There was a general trend for intra-generational migrants to be taller than non-migrants, by on average from 1.4 cm in fathers to 2 cm in sons. The inter-generational difference was 0.66 cm and was borderline significant. There were no significant differences in mean weights between migrants and non-migrants in either geographically mobile groups either intra- and inter-generationally. For BMI migrating fathers had, on average, a lower BMI than sedentes, but there was no significant intra-generational difference for sons although the directionality was maintained. Analysis of the inter-generational migration revealed that migrants had, on average, a lower BMI (Table 3).

Intra- and inter-generational migration in respect of in- and out-migrants

The pattern of migration was examined further by distinguishing between in- and out-migrants. The mean differences in height, weight and BMI between in-migrants

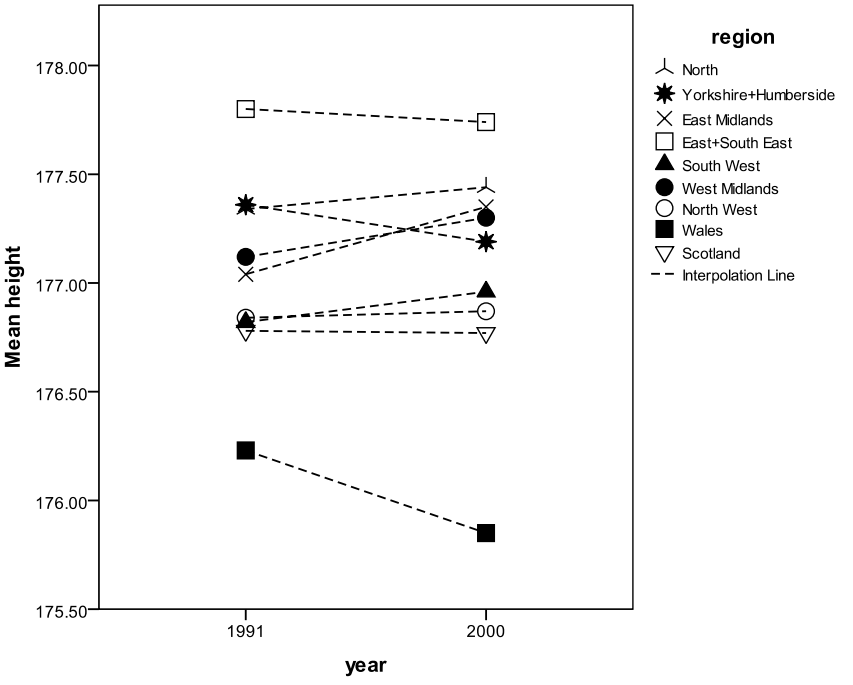

Fig. 2. Sons' height variation by region.

Table 2. ANOVA for regional variation of height, weight and BMI

		Height		Weight		BMI	
Generation	Year	*F*	*p*	*F*	*p*	*F*	*p*
Fathers	1958	6.343	<0.001	1.715	0.090	2.857	0.004
	1965	5.781	<0.001	2.091	0.034	3.047	0.002
	1969	5.416	<0.001	2.293	0.019	3.228	0.001
	1974	5.728	<0.001	2.055	0.037	3.002	0.002
Sons	1991	1.282	0.248	0.731	0.664	0.994	0.439
	2000	1.372	0.204	0.837	0.570	1.008	0.428

and non-migrants and out-migrants and non-migrants in height, weight and BMI were analysed and the net effect of migration (the difference between in- and out-migrants) was also calculated.

Figures 7–10 summarize these analyses for height and BMI (as there were no significant differences for weight, no figures are shown). A positive sign indicates that migrants were taller or had a higher BMI, on average, than non-migrants or that the net effect of in- and out-migration was positive. For fathers, in-migrants for height were taller, on average, in six of the nine regions, with the greatest difference being

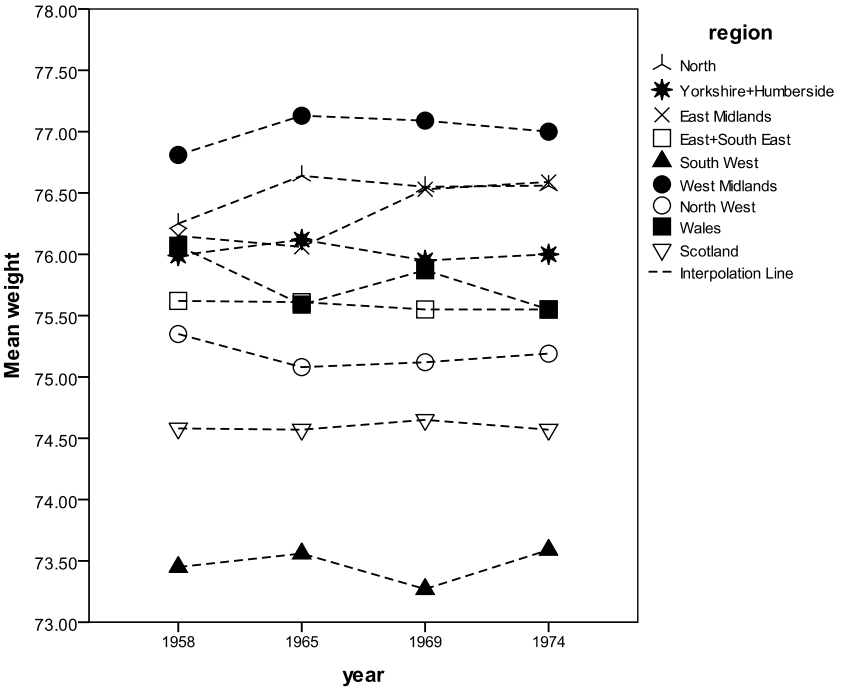

Fig. 3. Fathers' weight variation by region.

in the North and West Midlands regions. The tallest in-migrants among fathers came into the North region (3.0 cm above non-migrants, Fig. 7A); the tallest out-migrants among fathers came from Yorkshire & Humberside (3.5 cm taller, on average, than non-migrants) and the shortest came from Scotland (0.9 cm below non-migrants) (Fig. 7B). The net effect of migration (Fig. 7C) revealed that the largest positive gain on fathers' height was in the West Midlands region and Scotland (3.38 cm and 3.28 cm, respectively), while negative effects were found in the Yorkshire & Humberside, East Midlands and East & South-East regions by between 0.75 cm and 3.72 cm.

For sons (Fig. 8A) in-migrants were, on average, taller in all regions except Wales, with the largest differences between in-migrants and non-migrants being in London and the South-East (+3.69 cm) and South-West (+2.56). For out-migrants (Fig. 8B), the tallest (3.36 cm above sedentes) sons came from Wales, while the shortest (1.3 cm below non-migrants) came from the East Midlands region. The net effect of migration showed that the North, East Midlands, East & South-East and West Midlands regions were net gainers (Fig. 8C) while Wales and Scotland, in particular, were net losers.

For BMI among fathers, in-migrants (Fig. 9A) in seven of the nine regions were, on average, of lower BMI than non-migrants, particularly in Wales and Scotland (-2.14 and -1.82 kg m^{-2}, respectively). For out-migrant fathers (Fig. 9B), the North-West (+0.10 above the mean for sedentes) and South-West regions (+0.33 above) were the only two regions showing positive values, with the largest negative

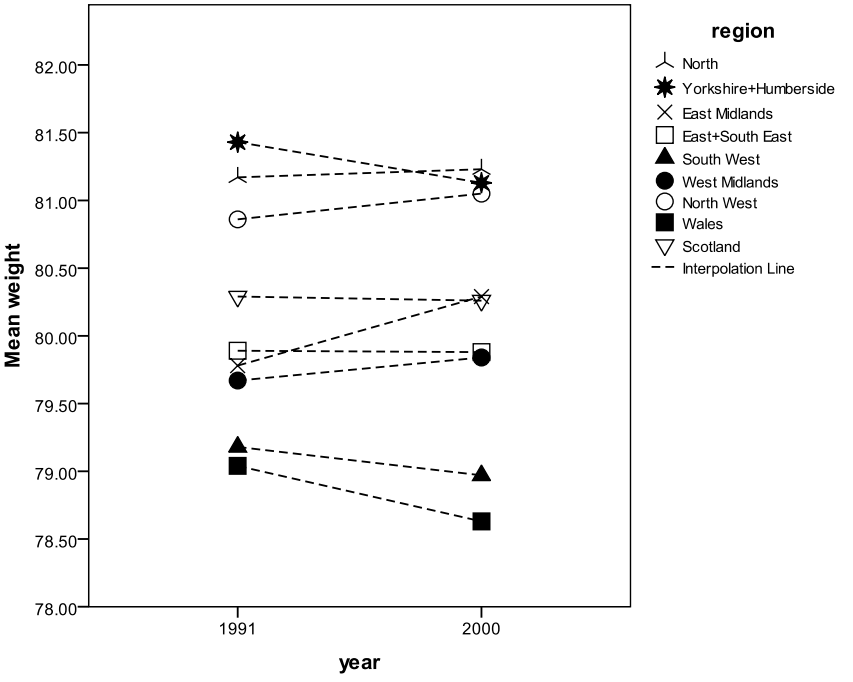

Fig. 4. Sons' weight variation by region.

values being found in the East Midlands and Yorkshire & Humberside regions (−0.95 and −0.98, respectively). The net effect of migration (Fig. 9C) indicated that in four regions there was a positive effect, the largest gains being in the East Midlands and Yorkshire & Humberside regions (+1.38 and 1.00, respectively) and largest losses in Scotland (−1.48) and Wales (−1.46).

For sons the results of inter-generational migration for BMI are shown in Fig. 10. In-migrating sons into the North-West (0.22 greater) and Wales (0.42 greater) had higher BMI, on average, than sedentes, while in-migrants into Yorkshire & Humberside were, on average, 2.30 lower in BMI (Fig. 10A). In all regions out-migrants had lower BMI than non-migrants, from −0.10 in Wales to −0.86 in Yorkshire & Humberside (Fig. 10B). The net effect of migration revealed that six of the nine regions were net gainers, particularly the North-West (+1.04), while Yorkshire & Humberside was a net loser (−1.44, Fig. 10C).

Discussion

Geographical variation in anthropometric traits has been described in many countries: Canada (Reeder *et al.*, 1997; Shields & Tjepkema, 2006), Finland (Jokela *et al.*, 2009), India (Dey & Debray, 2003), Peru (Shin, 2007), Poland (Hulanicka *et al.*, 1999), Sweden (Rasmussen *et al.*, 1999), Turkey (Iseri & Arslan, 2009), United States

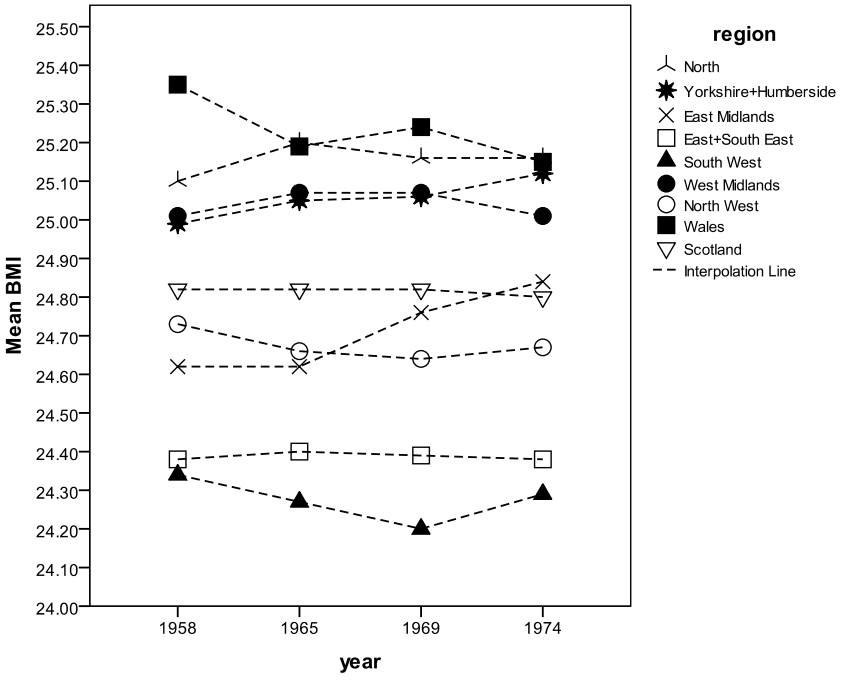

Fig. 5. Fathers' BMI variation by region.

(Jackson *et al.*, 2005) as well as Great Britain (Rona & Altman, 1977; Rosenbaum *et al.*, 1985; Scarborough & Allender, 2008).

This study's findings showed highly significant regional variation in height in the fathers' generation. Men from the East & South-East region were the tallest, while the shortest came from Wales. The overall mean height difference between regions ranged from about 2.7 cm to 3.1 cm (Fig. 1). The geographic variation in height found in this study is consistent with earlier research (Mascie-Taylor, 1984; Mascie-Taylor & Boldsen, 1985), which showed that the shortest males were in Wales and Scotland and the tallest in the South-East together with the Southern and Eastern regions. Geographical variation in height has also been reported in the British National Cohort (NCDS) by Strachan *et al.* (2007), as well as in other British data (Knight & Eldridge, 1984; Elford *et al.*, 1990). In these surveys men examined in the South were taller on average than those from Scotland. Men from the North, Midlands and Wales were of intermediate height. The present study's findings are also in agreement with the Rosenbaum *et al.* (1985) study. People living in Wales were shorter than others; those living in Scotland were the second shortest group, but those living in the East of England and South-East were around 1 cm taller than those living in the North.

Regional differences in BMI have been investigated by Waldhör *et al.* (2003), Ekblom *et al.* (2004), Schober *et al.* (2007) and Strachan *et al.* (2007). Higher mean BMI was reported in small towns or the countryside in Sweden (Ekblom *et al.*, 2004).

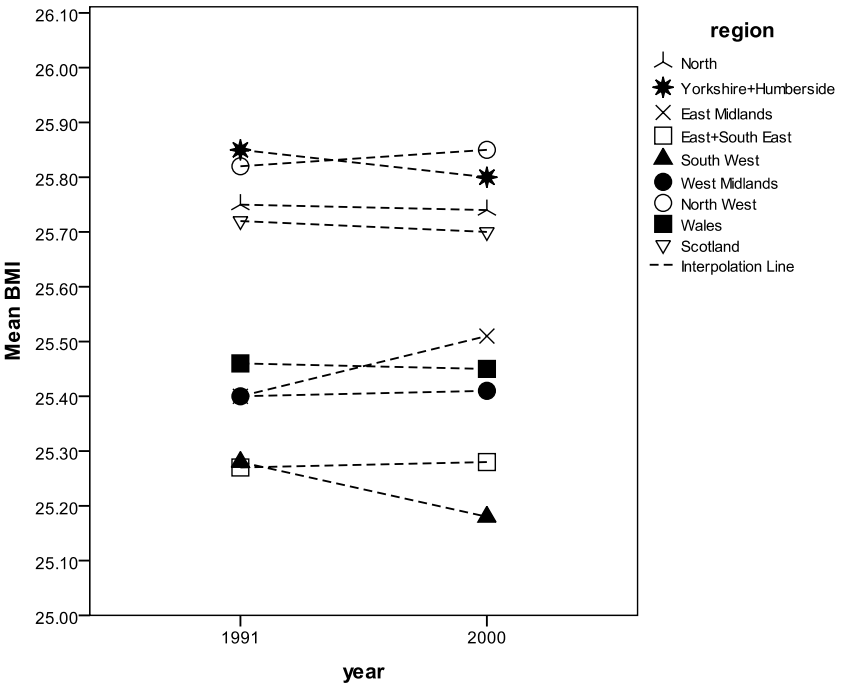

Fig. 6. Sons' BMI variation by region.

A clear east–west gradient in BMI was observed in Austria (Waldhör *et al.*, 2003; Schober *et al.*, 2007). There were some areas in the south and north-west of Spain with a higher BMI than the rest of the country (Gutiérrez-Fisac *et al.*, 1999). However, there are some examples where an 'obesogenic environment' seems to be similar across different degrees of urbanization (Gast *et al.*, 2007; Peytremann-Bridevaux & Santos-Egglma, 2007) or across geographical areas (Lahti-Koski *et al.*, 2008). In the present study there were much greater differences in mean BMI between regions (Figs 5 and 6) and less in weight (Figs 3 and 4). The highest mean weight was generally in the West Midlands, while the lowest was in the South-West region. For BMI the highest mean value was in Wales and the North, and the lowest, similar to weight, in the South-West region. Strachan *et al.* (2007) found the greatest BMI in Wales and Scotland. Similar results, especially for BMI, were reported by Rosenbaum *et al.* (1985). Rennie & Jebb (2005) observed small regional differences in overweight and obesity within England. They noticed that the prevalence of obesity in Scotland and Wales was greater than in England.

Studies on the relationship between geographical migration and body height are well known (Kobyliansky & Arensburg, 1977; Kim, 1982; Wheeler & Tan, 1983; Bernis, 1984; Steegmann, 1985; Singh & Harrison, 1996) and many researchers have found that both internal and international migrants are taller than non-migrants (Bernis, 1984; Mascie-Taylor, 1984; Danubio *et al.*, 2005; Szklarska *et al.*, 2008), which was clearly confirmed in the present study. Migrants were taller, on average,

Table 3. Mean height, weight and BMI for non-migrants and migrants: Student's *t*-test results

	Height					Weight				BMI			
Geographical migration	*N*	Mean	%	*t*	*p*	*N*	Mean	*t*	*p*	*N*	Mean	*t*	*p*
Fathers: 1958–1974													
Non-migrants	1895	174.82	90.7	2.537	0.011	1888	75.62	0.273	0.785	1888	24.75	2.100	0.036
Migrants	195	176.17	9.3			194	75.41			194	24.28		
Sons: 1991–2000													
Non-migrants	1949	177.11	93.2	3.414	0.001	1919	80.07	0.361	0.718	1919	25.51	1.485	0.138
Migrants	141	179.11	6.8			138	80.47			138	25.03		
Fathers–sons: 1958–2000													
Non-migrants	1626	177.10	77.8	1.884	0.060	1600	80.32	1.549	0.122	1600	25.59	2.650	0.008
Migrants	464	177.76	22.2			457	79.29			457	25.08		

Fig. 7. Mean difference in fathers' height among in- (A) and out-migrants (B) and the net effect (C). (Y+H=Yorkshire & Humberside; East M=East Midlands; West M=West Midlands; NW=North-West).

than non-migrants by 1.4 cm in fathers and 2 cm in sons (Table 3). Similar results on NCDS data were reported by Mascie-Taylor (1984) and Strachan *et al.* (2007).

The relation between geographical migration and BMI has also been studied but the results are not consistent between studies. For example, Danubio *et al.* (2005) pointed out that Italian immigrants to the USA had a higher prevalence of obesity

Fig. 8. Mean difference in sons' height among in- (A) and out-migrants (B) and the net effect (C).

than the contemporary US sample, while Park *et al.* (2009) found a lower chance of obesity among all immigrants. Tunisian migrants into France were found to be less overweight than the French (Méjean *et al.*, 2007), while migrant children of Turkish, Russian and Polish origin had a higher prevalence of overweight and obesity than those native-born in Germany (Will *et al.*, 2005). Similarly, internal Senegalese migrants had a higher BMI than non-migrants (Garnier *et al.*, 2003). The present

Fig. 9. Mean difference in fathers' BMI among in- (A) and out-migrants (B) and the net effect (C).

study did not show any differences in weight between geographically mobile groups in either fathers and sons, but migrating fathers had a lower BMI than sedentes. The results among fathers are consistent with a previous study on the NCDS (Strachan *et al.*, 2007).

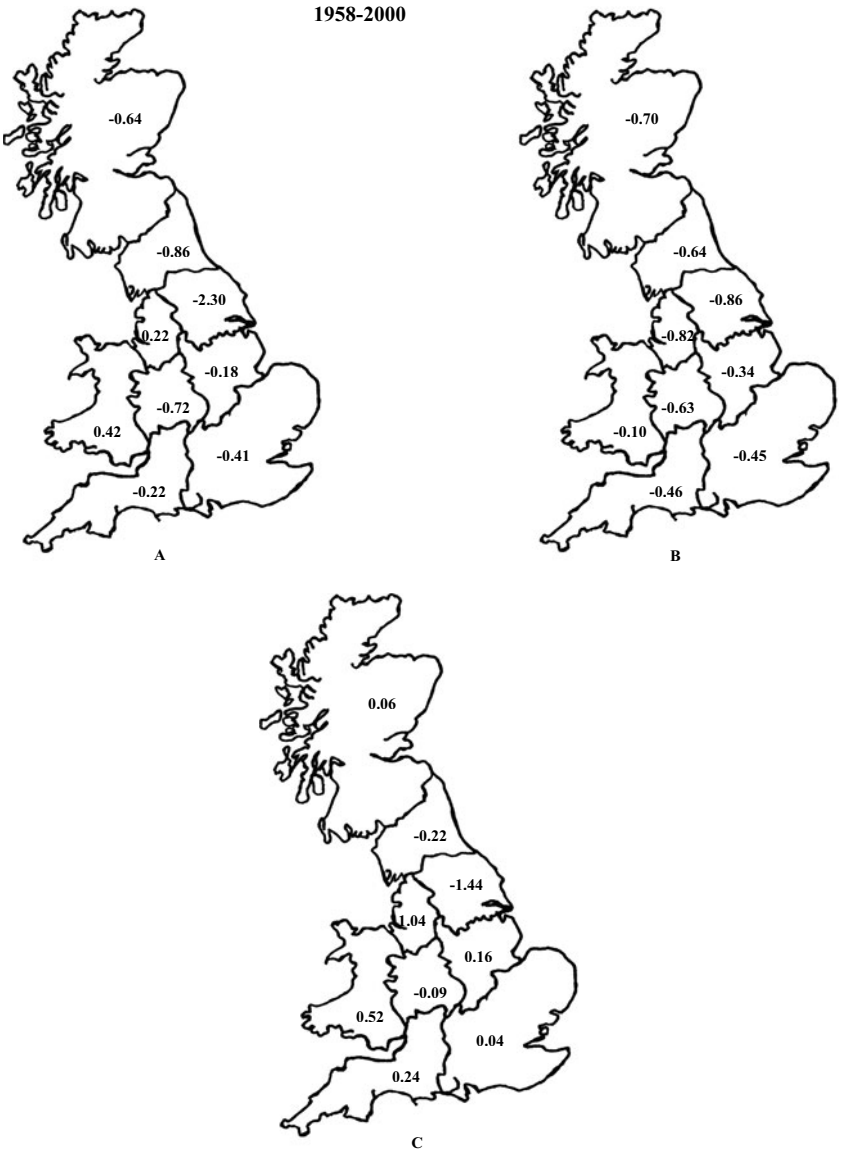

Fig. 10. Mean difference in sons' BMI among in- (A) and out-migrants (B) and the net effect (C).

The results on father–son pairs confirm that there is selective migration in relation to height and BMI. It appears that people who were geographically mobile within Britain in the second half of the twentieth century tended to be taller and have lower BMI than non-migrants.

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