Obesity, Hypertension, and Migration: A Meta-Analysis of Populations of the South Asian Diaspora

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Abstract The effects of migration on human health have been a topic of interest for demographers and human biologists. Even if migrants to a new region achieve a higher standard of living in their new place of residence, their improved living conditions may not be associated with better health. Part of the difficulty of understanding the health consequences of migration is the complications in trying to control for variables that may affect health, such as gender, age, and urban or rural environment of migrants and nonmigrants. In this paper we report results of a meta-analysis of the body mass index (BMI) and blood pressure (BP) of people of South Asian descent, by comparing nonmigrants who inhabit the subcontinent, with migrants who moved to various places around the globe. Our results indicate that BMI almost always increases to a significant level upon migration and that an increase in BMI is most pronounced in female migrants. Our results also show that BP does not always increase in migrant communities and that it is actually lower in some migrant samples than it is in comparable nonmigrant groups. Therefore, our results show that BP and the BMI do not behave in the same manner following a migration event. We propose that the BMI changes experienced by migrants are likely to reflect different activity levels and diet in the new homeland. However, the BP changes experienced by migrants are likely to reflect stress broadly defined. Such stress may be increased or decreased, depending on the specific migration experience. We propose that the BMI and BP measure two different dimensions of the migration experience.

A question that has vexed human biologists for years is whether the health of migrants is better or worse than that of nonmigrants (Gage, 2000). Although migrants might move to new areas with the hope of improving their standard of living—a hope that may become a reality—the health effects of this change may

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not necessarily be positive. For migrants, the move away from their place of origin may result in stress associated with the loss of the homeland and social support and the adoption of a new way of life. A new life style may be particularly deleterious if it is associated with decreased physical activity and increased consumption of commercial foods, changes frequently experienced by rural-to-urban migrants (Kusuma et al., 2002). However, it is also possible for some rural-to-urban migrants to experience improved health outcomes if the migration takes place in a region where medical facilities and services are located in the urban areas (Godfrey and Julien 2005). Thus, an investigation of whether migration results in better or worse health outcomes should differentiate the stress associated with migration from possible (though not necessary) unhealthy changes in lifestyle.

When the question is how migration affects the body mass index (BMI) and blood pressure (BP), several researchers stress the importance of investigating gender, age, and ethnic differences in morbidity, before making broad generalizations about the effects of migration on health. For example, Schall (1995) notes that among Pacific women, age is a better predictor of hypertension than is modernization, whereas among Pacific men, modernization is a better predictor of higher BP than is age. Indeed, several researchers note that the effect of migration on BMI and BP is gender specific (Borders et al. 2006; Bruce et al. 2007; Gloria-Bottini et al. 2007; Newell-Morris 1995; Nirmala 2001; Schall 1995). Therefore, a clinical question such as whether BMI and BP increase with migration is best understood by incorporating cultural information such as gender roles.

As the previous discussion shows, if we are to investigate the question of whether migration away from the homeland results in poor health outcomes as measured by BMI and BP, it is wise to approach such a question by looking at the genders separately, while controlling for age, ethnicity, and urban/rural environment. In this paper, we attempt to do so by performing a meta-analysis of populations of South Asian ancestry who were researched in urban and rural environments within the Indian subcontinent and away from it. By focusing on South Asian diaspora populations, we are able to compare the health of human groups with ancestry to a specific region who have migrated to both urban and rural environments outside of India, with those who inhabit urban and rural environments within the subcontinent. In this paper, we refer to the people from the area that was prepartition India and now consists of India, Pakistan, Sri Lanka, and Bangladesh with the term South Asian.

South Asian people migrated as indentured servants to many regions of the world, from Africa to Fiji to the Caribbean, starting in the 1860s (McKeigue et al. 1989). In general, these overseas communities have maintained a strong sense of cultural identity, one that is reflected in a high rate of endogamy (van der Veer 1995; Vertovec 2000). A few groups, such as those of Jamaica and Costa Rica, were small in numbers and have not been able to remain as culturally distinct as have those of other regions such as Guyana, Trinidad, and Fiji (Castri et al. 2007; Madrigal et al. 2007).

Our literature search indicated that the most commonly reported measures of cardiovascular health are systolic and diastolic BP (SBP and DBP, respectively) and the BMI (computed as $BMI = \frac{kg}{m^2}$). Thus, we only investigate the distribution of these two variables across the samples and do not include data on atherosclerosis and other measures of coronary heart disease (Enas et al. 1992).

Our review is based on data published after 1989 to avoid overlap with previous studies and to investigate if a migrant/nonmigrant, gender, and age effect on BMI and BP is present during these last decades of rapid modernization. We do include in our data analysis one study from the mid-1980s (Beckles et al. 1985), because it reports data from the Caribbean, an area of the world from which data on BMI and BP are rare.

Our purpose is not to investigate whether urban and rural populations within the subcontinent differ in health measures. In our opinion, this question has been conclusively settled by numerous and extensive reviews. Urban groups have increased BMI and BP when compared with rural ones (Agyemang and Bhopal 2002; Greenhalgh 1997; Gupta 2004; Gupta et al. 1979, 1996; Karlsen et al. 2001; Kusuma et al. 2008; McKeigue et al. 1989; Nishtar 2002; Zaman and Brunner 2008). Indeed, while hypertension, obesity, and other cardiovascular problems have become a true public health menace in India (Goyal and Yusuf 2006; Nishtar 2002; Reddy et al. 2005) some of the lowest prevalence rates of hypertension ever reported in the world were found in rural India (Kearney et al. 2004). Thus, our main question, using data from the late 1900s and early 2000s is: Do migrants of South Asian ancestry residing outside of the subcontinent differ in their BMI and BP from comparable South Asian subjects residing in the subcontinent? We approach this question by controlling for the effects of gender, age, and urban/rural environment of the subjects. Because few rural migrant samples were found, most of the comparisons involve urban subjects.

Materials and Methods

The Data. An exhaustive literature search was carried out using PubMed and Web of Knowledge and by "hand-searching" appropriate journals. We focused on papers that were published after 1989 (with one exception, Beckles et al. 1985) and, as noted above, that sampled adults only and specified the gender and age range of its subjects and whether the subjects lived in urban or rural environments.

Some papers could not be considered because the manner in which they measured hypertension or obesity was unusual, and no or few other papers used such measure. For example, whereas most authors report the prevalence rate of BMI using two cutoff points, namely ≥ 25 for overweight and ≥ 30 for obesity, some authors report the prevalence rate of BMI $\geq$ 27 or of ≥ 23 (Jafar et al. 2008; Kutty et al. 1993; Sarkar et al. 2005). In the same manner, whereas most authors use standard cutoff points of hypertension prevalence, such as BP $\geq$ 160/95 or BP $\geq$ 140/90, a few others report hypertension prevalence where hypertension is measured as BP $\geq$ 130/85. All papers that used unusual cutoff points, whether for hypertension or overweight and obesity, were excluded from the statistical analysis. We were also unable to use data from papers that did not break down the information by urban/rural environment (Chhabra and Chhabra 2007), that collected data on samples not clearly urban or rural (Zargar et al. 2000), that reported data by the clinical status of the subjects (Mohan et al. 2001; Ramachandran et al. 1999), or that included subjects under 18 years of age (Bharati et al. 2007; Ghosh 2007; Majumder et al. 1994; Rout 2009). Our aim was to obtain as many papers as possible that used the same measures of obesity or hypertension in adults within a specific age category and that noted the subjects' environment (urban or rural) and gender. Eight appendix tables, which can be accessed at http://anthropology.usf.edu/faculty/madrigal/ (scroll down to "Recent Journal Articles" and look for this paper's title) show our data set. The number that appears in the appendix table is the one that we use to identify a paper as a source of data shown in our data set.

Methods. We divided the samples into two broad age categories: $\geq$18 and $<$30 years and $\geq$30 years of age (hereafter referred to as 18+ and 30+, respectively). Attempts to narrow the age groups only resulted in an exceedingly small number of samples, which could not be submitted to statistical tests.

The mean BMI was compared between migrants and nonmigrants using a Mann-Whitney *U* test because the number of samples was small and because BMI was not normally distributed. In our analysis of mean BMI, the unit of analysis is the sample mean, not the individuals reported by each study. Because few papers report means for comparable subjects, the sample size of these tests is small. Therefore, not many questions could be successfully addressed with the mean data. The number of studies that report the mean SBP and DBP in subjects of comparable age, gender, and urban/rural status is small and is not amenable to statistical testing. Thus, all analyses of hypertension are done by comparing prevalence rates.

The prevalence rates of overweight (BMI $\geq$ 25), obesity (BMI $\geq$ 30), and hypertension (defined as BP $\geq$ 160/95 or using hypertensive drugs or as BP $\geq$ 140/90 or using hypertensive drugs) were analyzed with the Mantel-Haenszel χ^2 (Gupta et al.1996; Schall 1995). This type of χ^2 analysis is ideally suited for our purposes because it works with ordinal variables such as age categories. In these tests, the unit of analysis is the individual subject of the studies. Therefore, the sample size (by using all subjects in comparable studies) is not small, and we were able to test hypotheses with greater confidence than when we worked with the sample means. When the Mantel-Haenszel χ^2 test is applied to a 2 $\times$ 2 table, measures of relative risk (RR) are also obtained (Osborone 2006). The RR quantifies the risk that an individual in a category, such as being a migrant, will be more likely to suffer from obesity or hypertension than individuals in another

Table 1. The Mean BMI of Migrant and Nonmigrant Groups

Place of Residence	*Gender*	*Mean BMI*	*Sources*
Indian subcontinent	Females	21.59 ($n = 15$)	*
	Males	21.17 ($n = 14$)	**
Migrants	Females	26.57 ($n = 26$)	***
	Males	24.95 ($n = 29$)	****

$X^2_{\text{females, Indian subcontinent and migrant}} = 22.19$, df = 1, $p < 0.0001$.
$X^2_{\text{males, Indian subcontinent and migrant}} = 20.81$, df = 1, $p < 0.0001$.
$X^2_{\text{males and females, Indian subcontinent}} = 0.03$, df = 1, $p = 0.86$.
$X^2_{\text{males and females, migrant}} = 12.33$, df = 1, $p < 0.0003$.
*43, 25, 34, 22, 5, 17, 38, 34.
**25, 34, 22, 5, 17, 38, 34.
***37, 11, 12, 13, 20, 14, 27, 1, 23, 28, 10, 38, 29, 8, 44, 32, 5, 31, 35.
****37, 11, 12, 13, 36, 20, 14, 27, 1, 23, 28, 10, 38, 7, 45, 7, 29, 8, 44, 30, 5, 2, 31.

category, such as living in the Indian subcontinent. If the RR includes 1 within its 95% confidence limit, then the RR is not significant at the 0.05 level and is not reported. In a few cases, the RR is not significant at the 0.05 level, even though the X^2 (which tests the hypothesis of no association between the two variables in the table) is. We report the RR as the risk of the first category in comparison with the risk of the second category. For example, the RR of suffering from obesity among migrant males residing in South Africa is significantly lower than that of females at 0.70, with a confidence interval under 1 (Table 2). To clarify that males have lower relative risk of obesity than females, the X^2 of this comparison was written as follows: $X^2_{\text{males and females, South Africa}} = 55.6720$, df = 1, total sample size = 431, $p < 0.0001$, RR = 0.7061 (0.6417–0.7769).

We were able to analyze the prevalence of obesity and hypertension (using both definitions) in subjects 18+ and 30+ years of age. For overweight, we had to group all subjects in an 18+ age category because there were not enough subjects of age 30+ reported.

Because our research question required us to perform numerous statistical tests, we applied Bonferroni's correction to our α level (Morrison 1976). Thus, we will only consider a result to be statistically significant if its p values is ≤ 0.0008 (0.05/62), where 62 is the total number of statistical tests in the paper. All statistical analyses were performed with SAS 9.3.

Results

BMI in South Asians Living in the Subcontinent and Abroad. When we attempted to divide the sample means by migrant status, age category, urban/rural environment, and gender, we were reduced to dealing with exceedingly small numbers. Therefore, we were unable to test if migration results in a significantly different mean BMI in subjects of comparable age and rural/urban environment. Acknowledging that it would be preferable to control for such

Table 2. The Prevalence of Obese Urban Subjects in Trinidad, England, and the Indian Subcontinent

Region	*Number of Nonobese Subjects*	*Number of Obese Subjects*	*Prevalence of Obesity*	*Sources*
South Africa				
Females	150	72	32.43	37
Males	200	9	4.31	37
Trinidad				
Females	146	48	24.74	3
Europe				
Females	777	254	24.64	23,8,33,32
Males	697	94	11.88	23,8, 33
Indian subcontinent				
Females	90	15	14.29	15
Males	243	8	3.19	15

Subjects are ≥30 years of age.

$X^2_{\text{females, South Africa and Indian subcontinent}}$ = 11.9847, df = 1, total sample size = 327, p = 0.0005, RR = 2.2703 (1.3694–3.7638).

$X^2_{\text{females, Trinidad and Indian subcontinent}}$ = 4.4641, df = 1, total sample size = 299, $p < 0.0346$, RR = 1.7320 (1.0206–2.9393).

$X^2_{\text{females, Europe and Indian subcontinent}}$ = 5.64, df = 1, total sample size = 1136, $p < 0.01$, RR = 1.7245 (1.0666–2.7885).

$X^2_{\text{males, South Africa and Indian subcontinent}}$ = 0.4003, df = 1, total sample size = 460, p = 0.5269.

$X^2_{\text{males, Europe and Indian subcontinent}}$ = 16.3026, df = 1, total sample size = 1042, $p < 0.0001$, RR = 3.7285 (1.8373–7.5666).

$X^2_{\text{males and females, South Africa}}$ = 55.6720, df = 1, total sample size = 431, $p < 0.0001$, RR = 0.7061 (0.6417–0.7769).

$X^2_{\text{males and females, Europe}}$ = 47.08, df = 1, total sample size = 1822, $p < 0.0001$, RR = 0.8553 (0.8191–0.8931).

$X^2_{\text{males and females, Indian subcontinent}}$ = 15.05, df = 1, total sample size = 356, p = 0.0001, RR = 0.8854 (0.8163–0.9603).

variables, we compared all migrant sample means with all nonmigrant sample means, controlling only for gender. Our results indicate that migrants of both genders are significantly heavier than nonmigrants. In addition, the difference in mean BMI of migrating males and females is significant, with the migrant females having a significantly larger BMI than migrating males (Table 1). Therefore, migration appears to affect females in a particularly strong manner.

The prevalence of obesity by gender in urban subjects at least 30 years of age in South Africa and Trinidad (females only), Europe (UK, Netherlands, and Norway), and the Indian subcontinent is shown in Table 2. Obesity is significantly more prevalent in female migrants residing in South Africa and in male migrants residing in Europe than in comparable nonmigrant subjects. In addition, females in South Africa, India, and England are obese significantly more frequently than are males (Table 2).

We determined that the prevalence of obesity in urban subjects at least 18 years of age in India is low (4.45 in females and 1.01 in males), whereas it is uniformly higher in all migrants of both genders (Table 3). For females, the difference between South Asians residing in the subcontinent and migrants

Table 3. The Prevalence of Obese Urban Subjects in Singapore, Australia, England, and the Indian Subcontinent

Region	*Number of Nonobese Subjects*	*Number of Obese Subjects*	*Prevalence of Obesity*	*Sources*
South Africa				
Females	221	80	26.58	37
Males	290	10	3.33	
Singapore				
Females	655	135	17.09	21,13,4
Males	712	52	6.81	21,13,4
Australia				
Females	49	8	14.04	27
Males	63	5	7.35	27
England				
Females	241	118	32.87	6
Indian Subcontinent				
Females	322	15	4.45	25, 24
Males	294	3	1.01	25, 24

Subjects are ≥18 years of age.
ns, not significant.
$X^2_{\text{females, South Africa and Indian subcontinent}} = 56.9503$, df = 1, total sample size = 519, $p < 0.0001$, RR = 14.4850 (5.3880–38.9413).
$X^2_{\text{females, Singapore and Indian subcontinent}} = 32.6691$, df = 1, total sample size = 1127, $p < 0.0001$, RR = 6.7382 (2.1207–21.409).
$X^2_{\text{females, Australia and Indian subcontinent}} = 8.1263$, df = 1, total sample size = 394, $p < 0.0044$, RR = 3.1532 (1.4015–7.0942).
$X^2_{\text{females, England and Indian subcontinent}} = 90.6854$, df = 1, total sample size = 696, $p < 0.0001$, RR = 7.3846 (4.4066–12.3750).
$X^2_{\text{males, South Africa and Indian subcontinent}} = 0.00$, df = 1, total sample size = 716, ns.
$X^2_{\text{males, Singapore and Indian subcontinent}} = 14.6042$, df = 1, total sample size = 1061, $p = 0.00001$, RR = 6.7382 (2.1207–21.4092).
$X^2_{\text{males, Australia and Indian subcontinent}} = 10.3556$, df = 1, total sample size = 365, $p = 0.0.0013$, RR = 7.2794 (1.7827–29.7237).
$X^2_{\text{males and females, South Africa}} = 63.6539$, df = 1, total sample size = 601, $p < 0.0001$, RR = 0.7595 (0.7074–0.8155).
$X^2_{\text{males and females, Singapore}} = 38.76$, df = 1, total sample size = 1554, $p < 0.0001$, RR = 0.8897 (0.8573–0.9232).
$X^2_{\text{males and females, Australia}} = 1.47$, df = 1, total sample size = 125, $p = 0.22$.
$X^2_{\text{females and males, Indian subcontinent}} = 6.7654$, df = 1, total sample size = 634, $p = 0.0093$, RR = 4.4065 (1.2883–15.0718).

residing in South Africa, Singapore, and England is statistically significant. Indeed, the South African migrants have a relative risk of obesity 14.4 times that of comparable South Asian females. The difference in prevalence rate between Singaporean migrant and nonmigrant males is also statistically significant, with the former having a RR of 6.7 compared with that of nonmigrants. A gender difference in the prevalence rate is significant in the South African and Singaporean samples, among whom the prevalence of obesity is significantly higher in females (Table 3).

The prevalence rate of overweight is significantly higher in migrant females 18+ years of age residing in Australia and England than in nonmigrants

Table 4. The Prevalence of Overweight Urban Subjects in Singapore, Australia, England, and the Indian Subcontinent

Region	*Number of Nonoverweight Subjects*	*Number of Overweight Subjects*	*Prevalence of Overweight*	*Sources*
Singapore				
Females	83	60	41.96	21
Males	126	31	19.75	21
Australia				
Females	27	30	52.63	27
Males	35	33	48.53	27
England				
Females	123	236	65.74	6
Males	118	207	63.69	6
Indian subcontinent				
Females	5840	2633	31.08	40,15,34
Males	5984	1484	19.87	40,15,34

Subjects are ≥18 years of age.
ns, not significant.
$X^2_{\text{females, Singapore and Indian subcontinent}} = 7.75$, df = 1, total sample size = 8616, $p = 0.005$, RR = 1.35 (1.1106–1.6415).
$X^2_{\text{females, Australia and Indian subcontinent}} = 12.25$, df = 1, total sample size = 8530, $p = 0.0005$, RR = 1.69 (1.3213–2.1711).
$X^2_{\text{females, England and Indian subcontinent}} = 188.66$, df = 1, total sample size = 8832, $p < 0.0001$, RR = 2.11 (1.9506–2.2942).
$X^2_{\text{males, Singapore and Indian subcontinent}} = 0.0015$, df = 1, total sample size = 7625, ns.
$X^2_{\text{males, Australia and Indian subcontinent}} = 34.4173$, df = 1, total sample size = 7536, $p < 0.0001$, RR = 2.4422 (1.9039–3.1326).
$X^2_{\text{males, England and Indian subcontinent}} = 351.9513$, df = 1, total sample size = 7793, $p < 0.0001$, RR = 3.20 (2.9180–3.5207).
$X^2_{\text{females and males, Singapore}} = 17.41$, df = 1, total sample size = 300, $p < 0.0001$, RR = 2.12 (1.4684–3.0752).
$X^2_{\text{females and males, Indian subcontinent}} = 260.08$, df = 1, total sample size = 15941, $p < 0.0001$, RR = 1.56 (1.4794–1.6530).
$X^2_{\text{females and males, Australia}} = 0.2071$, df = 1, total sample size = 125, $p = 0.6491$.
$X^2_{\text{females and males, Europe}} = 0.3124$, df = 1, total sample size = 684, $p = 0.5762$.

(Table 4). The male migrants residing in Australia and England have significantly higher prevalence rates than do nonmigrants. A gender difference is significant in Singapore and India, where the RR of females being obese is significantly higher than that of males.

BP in South Asians Living in the Subcontinent and Abroad. Tables 5 and 6 show the prevalence rate of hypertension defined as SBP ≥ 160 or DBP ≥ 95 in subjects at least 18 and 30 years, respectively, and Tables 7 and 8 show the prevalence of hypertension defined as SBP ≥ 140 or DBP ≥ 90 in subjects 18 and 30 years, respectively. Migrants who live in South Africa have consistently higher hypertension prevalence rates than do nonmigrants. This higher rate is significant for subjects 18+ and 30+ years of age of both genders (hypertension defined as SBP ≥ 160 or DBP ≥ 95; Table 5) and for males 30+ years of age

Table 5. The Prevalence Rate of Hypertension, Defined as SBP ≥ 160 or DBP ≥ 95, in Urban Subjects in South Africa, England, and the Indian Subcontinent

Region	*Hypertense Subjects*	*Nonhypertense Subjects*	*Prevalence Rate*	*Sources*
South Africa				
Females	69	153	31.08	37
Males	72	228	24.00	37
England				
Females	44	315	12.26	6
Males	33	292	10.15	6
Indian subcontinent				
Females	1701	10743	13.67	39,42, 9,18
Males	1014	7677	11.67	39, 9,18

Subjects are ≥18 years of age.
ns, not significant.
$X^2_{\text{females, South Africa and Indian subcontinent}} = 55.0219$, df = 1, total sample size = 12668, $p < 0.00001$, RR = 2.2742 (1.8604–2.7799).
$X^2_{\text{females, England and Indian subcontinent}} = 0.59$, df = 1, total sample size = 12805, ns.
$X^2_{\text{males, South Africa and Indian subcontinent}} = 41.5278$, df = 1, total sample size = 8991, $p < 0.0001$, RR = 0.8604 (0.8070–0.9173).
$X^2_{\text{males, England and Indian subcontinent}} = 0.6990$, df = 1, total sample size = 9016, ns.
$X^2_{\text{males and females, South Africa}} = 3.2387$, df = 1, total sample size = 522, $p = 0.0719$.
$X^2_{\text{males and females, England}} = 0.7536$, df = 1, total sample size = 684, ns.
$X^2_{\text{males and females, Indian subcontinent}} = 18.2805$, df = 1, total sample size = 21137, $p < 0.0001$, RR = 0.9774 (0.9673–0.9875).

(hypertension defined as SBP ≥ 140 or DBP ≥ 90; Table 8). Migrants to England 30+ years of age of both genders have significantly higher prevalence rates of hypertension if the condition is defined as SBP ≥ 160 or DBP ≥ 95 (Table 6). In contrast, the Singapore migrants of both genders age 18+ have significantly lower prevalence rates of hypertension (defined as SBP ≥ 140 or DBP ≥ 90) when compared with nonmigrants (Table 7).

A clear gender difference in hypertension prevalence rate does not emerge. Instead, the data shown in Tables 5–8 indicate that the males and females of many samples do not differ in their prevalence rate of hypertension. A higher prevalence rate in males as opposed to females is seen in the English sample of subjects 30+ years of age (hypertension defined as SBP ≥ 160 or DBP ≥ 95; Table 6) and in the Singapore sample of subjects 18+ years of age (hypertension defined as SBP ≥ 140 or DBP ≥ 90; Table 7). The only samples in which females had higher rates of hypertension were those of South Asian subjects living in the subcontinent, in subjects 18+ years of age (hypertension defined as SBP ≥ 160 or DBP ≥ 95; Table 5), and in subjects 30+ years of age (hypertension defined as SBP ≥ 140 or DBP ≥ 90; Table 8).

We were able to perform only one migrant/nonmigrant comparison based on rural subjects by using combined gender samples. The rural community of Indo-Costa Ricans does not differ significantly in its prevalence rate from rural nonmigrant South Asians (Table 9).

Table 6. The Prevalence Rate of Hypertension, Defined as SBP ≥ 160 or DBP ≥ 95, in Urban Subjects in South Africa, Singapore, England, and the Indian Subcontinent

Region	*Hypertense Subjects*	*Nonhypertense Subjects*	*Prevalence Rate*	*Sources*
South Africa				
Females	99	202	32.89	37
Males	67	142	27.31	37
Singapore				
Females	9	73	10.98	21
Males	19	74	20.43	21
England				
Females	158	480	24.76	10,33,44,8
Males	249	412	37.67	10,33,44,8
Indian subcontinent				
Females	165	790	17.28	39, 18
Males	207	992	17.26	39, 18

Subjects are ≥30 years of age.
ns, not significant.
$X^2_{\text{females, South Africa and Indian subcontinent}} = 33.5787$, df = 1, total sample size = 1256, $p < 0.0001$, RR = 1.9037 (1.5387–2.3552).
$X^2_{\text{females, Singapore and Indian subcontinent}} = 2.1456$, df = 1, total sample size = 1037, $p = 0.1430$.
$X^2_{\text{females, England and Indian subcontinent}} = 13.2563$, df = 1, total sample size = 1593, $p = 0.0003$, RR = 1.4334 (1.1809–1.7399).
$X^2_{\text{males, South Africa and Indian subcontinent}} = 24.8319$, df = 1, total sample size = 1408, $p < 0.0001$, RR = 1.8569 (1.4708–2.3442).
$X^2_{\text{males, Singapore and Indian subcontinent}} = 1.1854$, df = 1, total sample size = 452, $p = 0.2763$.
$X^2_{\text{males, England and Indian subcontinent}} = 95.8243$, df = 1, total sample size = 1860, $p < 0.0001$, RR = 2.1820 (1.8630–2.5555).
$X^2_{\text{males and females, Africa}} = 0.0389$, df = 1, total sample size = 510, $p = 0.8436$.
$X^2_{\text{males and females, Singapore}} = 0.5988$, df = 1, total sample size = 1292, $p = 0.4390$.
$X^2_{\text{males and females, England}} = 25.1116$, df = 1, total sample size = 1299, $p < 0.0001$, RR = 1.2070 (1.1208–1.2999).
$X^2_{\text{males and females, Indian subcontinent}} = 0.003$, df = 1, total sample size = 2154, ns.

Discussion

Do migrants experience better or worse health than nonmigrants? In this paper we focused on the question of whether migration out of the Indian subcontinent was deleterious to the migrants' health, as measured by BP and BMI, controlling for urban/rural environment, age, and gender. It is regrettable that we could only perform one comparison of these measures for rural nonmigrant and migrant groups, without being able to control for gender. Data on rural migrant South Asians are remarkably lacking, except for that collected in an Indo-Costa Rican group (Castri et al. 2007; Madrigal et al. 2007). We acknowledge the small sample size of the latter group, but we report these data because they fill an important void.

We were able to show that BMI and BP do not respond in the same manner to the migration experience. This difference can be best illustrated with female migrants 18+ years of age who reside in Singapore (Tables 3 and 7). These females

Table 7. The Prevalence of Hypertension, Defined as SBP ≥ 140 or DBP ≥ 90, in Urban Subjects from Singapore and the Indian Subcontinent

Region	*Hypertense Subjects*	*Nonhypertense Subjects*	*Prevalence Rate*	*Sources*
Singapore				
Females	71	576	10.97	4, 13
Males	110	497	18.12	4, 13
Indian subcontinent				
Females	1287	3519	26.78	19,24,41
Males	453	1088	29.40	19, 24

Subjects are ≥18 years of age.

$X^2_{\text{females, Singapore and Indian subcontinent}} = 76.1545$, df = 1, total sample size = 5453, $p < 0.0001$, RR = 0.4098 (0.3272–0.5126).

$X^2_{\text{males, Singapore and Indian subcontinent}} = 28.6080$, df = 1, total sample size = 2148, $p < 0.0001$, RR = 0.6165 (0.5119–0.7425).

$X^2_{\text{males and females, Singapore}} = 12.9467$, df = 1, total sample size = 1254, $p = 0.0003$, RR = 1.0873 (1.0382–1.1387).

$X^2_{\text{males and females, Indian subcontinent}} = 4.0168$, df = 1, total simple size = 6347, $p = 0.045$.

have a higher obesity rate (17.09) and a lower prevalence rate of hypertension (10.97) than do comparable nonmigrant females (4.45 and 26.78, respectively). That BMI and BP do not respond in the same manner to the migration experience also indicates that the question of whether migration has beneficial or deleterious effects on human

Table 8. The Prevalence of Hypertension, Defined as SBP ≥ 140 or DBP ≥ 90, in Urban Subjects from South Africa, England, and the Indian Subcontinent

Region	*Hypertense Subjects*	*Nonhypertense Subjects*	*Prevalence Rate*	*Sources*
South Africa				
Females	95	127	42.79	37
Males	94	115	44.98	37
England				
Females	91	161	36.11	8
Males	111	142	43.87	8
Indian subcontinent				
Females	1203	1392	46.36	39,18,22
Males	966	1736	35.75	39,18,22

Subjects are ≥30 years of age.

$X^2_{\text{females, South Africa and Indian subcontinent}} = 1.0461$, df = 1, total sample size = 2817, $p = 0.3064$.

$X^2_{\text{females, England and Indian subcontinent}} = 9.72$, df = 1, total sample size = 2847, $p = 0.0018$, RR = 0.7790 (0.6576–0.9227).

$X^2_{\text{males, South Africa and Indian subcontinent}} = 7.12$, df = 1, total sample size = 2911, $p = 0.0076$, RR = 1.2580 (1.0734–1.4737).

$X^2_{\text{males, England and Indian subcontinent}} = 6.5865$, df = 1, total sample size = 2955, $p = 0.0103$, RR = 1.2272 (1.0581–1.4233).

$X^2_{\text{males and females, South Africa}} = 0.2079$, df = 1, total sample size = 431, $p = 0.6468$.

$X^2_{\text{males and females, England}} = 3.16$, df = 1, total sample size = 505, $p = 0.075$.

$X^2_{\text{females vs. males, Indian subcontinent}} = 61.5796$, df = 1, total simple size = 5297, $p < 0.0001$, RR = 1.2967 (1.2147–1.3842).

Table 9. The Prevalence Rate of Hypertension, Defined as SBP ≥ 140 or DBP ≥ 90, in Rural South Asian and Indo-Costa Rican Combined-Gender Samples

Region	*Hypertense Subjects*	*Nonhypertense Subjects*	*Prevalence Rate*	*Sources*
Indian subcontinent	189	941	16.73	26
Costa Rica	5	31	13.89	*

Subjects are ≥18 years of age.
$X^2 = 0.20$, df = 1, total sample size = 1166, $p = 0.65$.
Source: Kutty et al. 1993.
*Madrigal et al., unpublished data.

health does not have a simple answer: are the female migrants residing in Singapore better off than comparable nonmigrant females because the former have lower hypertension rates, or are they worse off because they have higher levels of obesity? Which measure of wellness should we choose when we attempt to establish whether migration has negative effects on health?

It is important to stress that high levels of obesity are not always associated with high levels of hypertension (Madrigal et al. 2009) because it is frequently assumed that these two conditions are a consequence of migration and or modernization. This lack of congruence between BP and BMI is interesting, in light of the suggestion by Choh et al. (2001) that BMI shares additive genetic effects with BP.

In most comparisons, South Asian nonmigrant urban subjects have lower mean BMI, and lower prevalence rates of obesity and overweight than do migrants. The higher prevalence rate of overweight and obesity in migrant groups, both males and females, of 18+ or 30+ years of age was in some cases associated with exceedingly high relative risks. The difference in obesity and overweight between migrants and nonmigrants was particularly startling when we looked at the 18+ age samples, which shows that migration results in an increased BMI even in young subjects.

The analysis of overweight and obesity prevalence rates also showed that females frequently have significantly higher prevalence rates of these conditions than males. This difference was sometimes associated with very high relative risks of the conditions in females (this difference is staggering in the South African age 30+ sample, in which the females have a prevalence rate of obesity of 32.43, and the males have a prevalence rate of only 4.31; Table 2). Therefore, obesity and overweight are more common in females than in males, whether the subjects are migrants or not. Both biological and cultural factors contribute to explaining this gender difference. Although Ball et al. (2003) note that weight-related behaviors may account for differences in the prevalence of these conditions between the genders, Newell-Morris (1995) notes that from an evolutionary perspective, it is not surprising that males and females should respond differently in their fat deposition to their environment, because fat storage is of fundamental importance to reproduction in the human female.

There is no consistent difference in the BP of migrants and nonmigrants. Some migrants have lower (Singapore), some have higher (South Africa), and some have nondifferent BP from the BP of nonmigrants (England and Australia).

In addition, the rate of hypertension in males and females does not differ in most of the samples. Males have significantly higher rates of hypertension only in the British (Table 6) and the Singaporean (Table 7) samples. Interestingly, the only samples in which females have significantly higher hypertension prevalence rates reside in India (Tables 5 and 8).

Why do the migrant groups not have a clear pattern of increase in BP, whereas they do have one for BMI? According to several authors, BP reflects individuals' lifestyle incongruities and stress (Bitton et al. 2006). Dressler (2004) notes that changes in diet and physical activity associated with migration cannot account for the increase in BP seen in migrants. It is possible that some migrants have lower or higher BP than nonmigrants because the difficulties associated with lifestyle incongruities and low social support are worse, but sometimes they are better in the new environment than those encountered in the homeland. Thus, it is entirely possible that some migrants experience a positive change, whereas other migrants experience a negative change in stress after migrating. In addition, the difficulties of life after migration may affect males and females in the same migrant group differently, depending on the context-specific challenges they face (Dressler 1999; Dressler and Bindon 1997). Thus, some migrant females might be more buffered from the host culture than are males, which may shield the former from frequent cultural dissonance. Indeed, Dressler (1999) notes that an increase in BP of people who move to more "modernized" settings is more pronounced in males than in females in most, but not all studies. If hypertension (SBP $\geq$ 160 or DBP $\geq$ 95) is best understood as a reaction to stress, lifestyle incongruity, and lack of social support, our data indicate that male migrants (30+ years of age) are worse off than female migrants in England (Table 6). In the same manner, nonmigrating South Asian females (the only females whose BP is higher than that of males of the same sample) appear to be particularly vulnerable to stressful conditions.

Our paper suffers from limitations that do not allow us to further explore the reasons for the population-specific BP of males and females, compared with each other and compared between migrants and nonmigrants. It would be desirable to measure the lifestyle incongruity, lack of social support, and stress of these migrants and to determine if males and females are experiencing the migration process differently in each of the communities studied (Bitton et al. 2006; Dressler and Bindon 1997). We do note that the Encyclopedia of the South Asian Diaspora (Lal 2006) states that the socioeconomic status and level of political involvement is much higher among the Singaporean than among the South African migrants. This observation may help explain the consistently low BP of the former and the consistently higher BP of the latter.

Due to the nature of our data, we were also unable to perform the careful analysis done by Himmelgreen et al. (2004), who showed that the longer the time since migration, the greater the increase in obesity in migrant groups. Moreover, we do not know if the nonmigrant subjects are residing in urban areas now, but migrated to them from rural areas of the subcontinent. A further possible complicating factor is that migrants may have had different South Asian ethnicities, genetic backgrounds, and socioeconomic status, which may have caused them to be different from nonmigrants prior to the migration event. We acknowledge that were unable to control for these variables.

Our paper suffers from other shortcomings typical of meta-analyses: we did not measure all of the subjects with the same instruments, and we had to group subjects in very wide age categories to achieve adequate sample sizes. However, our paper fills an important void in the study of the effects of migration on human health: we were able to compare the BMI and BP of urban migrant and nonmigrant subjects with ancestry in one region, controlling for gender and for age. We acknowledge that we only considered two measures of cardiovascular health and that we were unable to include broader measures of health and well being.

BMI and BP measure two different dimensions of the migration experience. We suggest that BMI reflects changes in diet and physical activity, whereas BP reflects lifestyle incongruence, lack of social support, and stress. Whereas BMI almost always increases upon migration, BP increases, decreases, or remains unchanged upon migration.

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