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Patrick F. Clarkin, *University of Massachusetts Boston*

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RESEARCH PAPER

War, forced displacement and growth in Laotian adults

Patrick F. Clarkin

Department of Anthropology, University of Massachusetts Boston, Boston, MA 02125-3393, USA

***Background*: Evidence from several populations suggests that war negatively impacts civilian nutrition, physical growth and overall health. This effect is often enduring or permanent, particularly if experienced early in life.**

***Aim*: To assess whether the number of lifetime displacement experiences and being displaced in infancy were associated with adult height, sitting height, leg length and the sitting height ratio.**

***Subjects and methods*: Retrospective questionnaires on displacement and resettlement experiences and anthropometric data were collected from a sample of Laotian adult refugees (ethnic Hmong and Lao; $n = 365$). All were born in Laos or Thailand and had resettled in French Guiana or the US. Many had been displaced several times by military conflict in Laos.**

***Results*: In bivariate analyses, being displaced in infancy and the number of lifetime displacement experiences one had were negatively associated with final adult height and leg length in both sexes. The association was stronger in females, particularly Hmong females. There was no significant association between total displacement experiences and the sitting height ratio. In multiple regression analyses, linear growth in males was negatively associated with being displaced in infancy; in females, the number of lifetime displacement experiences was a significant predictor.**

***Conclusion*: Forced displacement from war appears to have a lasting effect on final adult height, sitting height and leg length, although not necessarily on the sitting height ratio in this sample.**

Keywords: Laos, height, sitting height, refugees, forced displacement

INTRODUCTION

War frequently creates conditions that are deleterious to civilian safety and health, often leading to a 'complex emergency' with increases in mortality, physical trauma, psychological stress, infection and malnutrition (Salama et al. 2004; Burnham et al. 2006). Multiple studies have found an association between exposure to war conditions and impaired infant and child growth and development, including reductions in birth weight (Smith 1947; Simic et al. 1995; Steckel 1998; Skokić et al. 2006). Cohort analyses reveal negative secular trends for child height or weight during the Second World War in many countries, including China, Japan, the Soviet Union, Germany, France, Italy, Belgium, Norway, Finland and the British Channel Islands (Keys et al. 1950; Markowitz 1955; Vlastovsky 1966; Kimura 1984; Angell-Anderson et al. 2004; Ellison and Kelly 2005; Clarkin 2010). For example, Brundtland et al. (1980) found that average height in children aged 8–13 years in Oslo increased from 1920 to 1940, declined noticeably during the war and then increased thereafter. While a comprehensive review of the impacts of war on childhood growth is beyond the scope of this article, high rates of growth retardation have been found in populations affected by more recent episodes of military conflict as well, including Guatemala, the Sudan, the Democratic Republic of Congo and among Rwandan refugees (Goma Epidemiology Group 1995; Bogin and Keep 1999; Deng 2002; Tschoegl et al. 2007).

Beyond wide temporal or geographical trends, specific elements of armed conflict such as forced displacement have been associated with malnutrition and growth retardation (Toole and Waldman 1993). In general, refugees and internally displaced people (i.e. refugees who have not crossed an international border) tend to have high rates of malnutrition (Yip and Sharp 1993; Grandesso et al. 2005; Roberts et al. 2009). In a sample of 1600+ Afghan children aged 0–59 months, Mashal et al. (2008) found that those who had been internally displaced in the previous 5 years were more likely to be stunted, underweight and wasted compared to children who were not displaced or who had fled the country and subsequently returned. Similarly, internally displaced children in eastern Burma were significantly more likely to be malnourished (assessed by mid-upper arm circumference) compared to non-displaced children (Mullany et al. 2007).

Correspondence: Patrick F. Clarkin, PhD, Department of Anthropology, University of Massachusetts Boston, Boston, MA 02125-3393, USA. Tel: 1-617-287-6858. E-mail: patrick.clarkin@umb.edu

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Forced displacement may lead to negative energy balance and be disruptive to child growth for many reasons (Toole and Waldman 1997). As involuntary migrants, refugees are usually forced to flee without time to prepare for the arduous journey to sanctuary. Loss of property, capital, family and social networks further exacerbates the ability of displaced persons to acquire food, particularly for children separated from their parents (Slim 2008). For internally displaced persons, access to international relief efforts is precarious due to safety concerns and, upon reaching safety, displaced persons are often resettled in less fertile areas than their former homes. In subsistence economies, agricultural cycles broken by war means that it could take months to grow new crops to fruition. Further, international refugees are often seen as burdens by host nations and may be placed in crowded, unsanitary conditions that may facilitate the spread of diarrheal and respiratory disease (Yip and Sharp 1993; Iqbal 2010).

A few studies have directly addressed whether war or forced displacement have long-term effects on linear growth that persist beyond childhood. In a sample of almost 70 000 men aged 18 years from the Netherlands, those who had been exposed prenatally to moderate or severe famine during the Second World War were shorter than unexposed controls (Neugebauer et al. 1999). Although the difference in height between the groups was statistically significant ($p < 0.001$), the absolute disparity was small (0.2–0.3 cm). However, in a smaller sample of middle-aged Dutch adults, there was no association between prenatal exposure to famine and adult height or other anthropometrics, such as leg length and sitting height (Stein et al. 2007). Similarly, in a sample of 5311 adults who had been exposed to extreme famine, cold and psychological stress at age 6+years during the siege of Leningrad, men were not significantly different in height compared to controls who lived outside of Leningrad at the time, while women who had been exposed to the siege were actually slightly taller (Koupil et al. 2007). A smaller study found comparable results, where adults exposed to the siege either prenatally or in infancy were not significantly different in height compared to controls (Stanner et al. 1997).

The objective of the current study was to explore whether adult height and other anthropometrics related to linear growth were associated with war-related hardships, specifically forced displacement, experienced earlier in life in a sample of Laotian refugees residing in the US and French Guiana. The rationale for looking at this particular population was that during the First and Second Indochina Wars (1945–1954 and 1958–1975, respectively), forced displacement of the civilian population in Laos was quite common, particularly in rural areas in the northeast and south, along the Ho Chi Minh trail. Fighting between rightist, communist and neutralist forces led to an estimated 200 000 deaths and the displacement of 750 000 people, in a nation of roughly 3 million people (Stuart-Fox 1997; Morikawa 1998). This was the direct result of combat between regular ground units and guerilla forces, as well as an aerial bombing campaign. Between 1964–1973, over 2 million tons of bombs were dropped on Laos by US air planes (Khamvongsa and Russell 2009), leading to a corresponding increase in the number of internally displaced persons during those years (USAID 1973). During this period, many internally displaced persons were forced to migrate multiple times, in some cases walking for days-to-months before reaching sanctuary, surviving on limited rations while on the move (Weldon 1999: 52).

METHODS

Study design

The study protocols in the Hmong and Lao samples included in this study have been described in detail elsewhere (Clarkin 2008, 2009). Prior to conducting research, this study was approved by the institutional review boards at Binghamton University (SUNY) and the University of Massachusetts Boston. In 2001–2002, convenience samples of ethnic Hmong were recruited in French Guiana ($n = 179$) and the US ($n = 100$). All individuals in the current analysis were born in either Laos or Thailand between 1940– 1985. The French Guiana sample represented ~25% of Hmong adults in this age range, while the American Hmong sample represented less than 1% of the communities where they were recruited (based on data from SEARAC 2004). A follow-up study using a similar protocol was conducted with a sample of Lao in the US ($n = 100$) in 2006, representing ~ 5% of adults from this particular age range in this community. Both groups originated in Laos, resettling abroad after the conclusion of the Second Indochina War in 1975.

Hmong in French Guiana are primarily farmers who live in rural, ethnically homogeneous villages and sell produce in the larger towns of that country. Hmong and Lao in the US are more heterogeneous in their living arrangements than those in French Guiana, although some broader trends can be delineated. In comparison to the US population overall, persons of Hmong and Lao tend to reside in urban areas, be of lower socioeconomic status, and are more likely to be linguistically isolated (SEARAC 2004). Those patterns largely hold true for the current sample, particularly for the Hmong. However, questionnaires revealed that the Lao in this sample were better off financially and in terms of education than national survey data and tended to come from more urban backgrounds in Laos than the Hmong (Clarkin 2009).

In both countries, potential participants were recruited by working through local social networks. The principal investigator and an interpreter then visited volunteers in their homes or at community gatherings (for example, a festival for the Hmong or a Buddhist temple for the Lao). The study protocol entailed the administration of questionnaires and anthropometric measurements, typically to a married couple as well as any adult volunteers present during the visit. Potential participants were excluded if they were pregnant, injured, an amputee or currently ill.

Questionnaires were retrospective, pertaining to participants' displacement experiences in Southeast Asia and the

age at which they resettled in their current place of residence. Relevant variables for the current analysis included date and place of birth, the total number of times (up to 6) one was displaced by the war, whether one was displaced during infancy (defined as before age 2 years) and one's age at resettlement in either the US or French Guiana. Forced displacement experiences included any episode one was induced to move as a result of conflict; this included internal displacements (i.e. within the borders of Laos) and international displacement (i.e. crossing from Laos to Thailand). Persons were asked to describe their displacement experiences in more detail, such as the town or village abandoned, the new place of refuge and the approximate age this occurred. For example, one individual, a 37 year-old male born in Xieng Khouang province in northern Laos, was forced to migrate six times because of the war, all before age 15 years. In a semi-structured interview, he described his journey walking between each destination. His six displacement experiences totalled at least 170 miles, assuming a direct route of travel between all destinations. However, it was not possible to obtain such level of detail for each individual; therefore, self-reported number of displacement experiences had to suffice as a proxy for overall exposure to war conditions. Participants were also asked directly, 'Did you ever have to leave your village because of war before age 2 years?' Age 2 years delineated the cut-off for infancy, when most growth retardation occurs (Martorell and Habicht 1986; Martorell 2010).

Anthropometric variables included height and sitting height, measured using a Seca height rod (model S-214), with height measured in bare feet or socks. Sitting height was measured by placing the Seca height rod platform on the surface of a portable folding chair carried between homes and other communal measuring site. Different chairs, but of equal height, were used in French Guiana and the US. All anthropometric measurements were taken by a single individual and care was taken to follow a standard protocol, following Lohman et al. (1988), although no formal test of statistical reliability was conducted. Leg (subischial) length was estimated as standing height minus sitting height. The sitting height ratio (SHR) was calculated as (sitting height/stature) $\times$ 100, with a higher SHR value indicating relatively shorter legs in proportion to total stature. SHR is felt to be a sensitive indicator of environmental conditions during pre-pubertal growth, a period when lower limbs grow more quickly than the torso or head (Bogin et al. 2002; Padez et al. 2009).

Statistical analysis

Statistical analyses were performed using SPSS 17.0 software (Chicago, IL). Fourteen individuals were excluded because of incomplete data or because they were born in the US or French Guiana. The final sample consisted of 365 individuals, including 164 Hmong males, 109 Hmong females, 60 Lao females and 32 Lao males. All individuals in the current analysis were born in either Laos or Thailand between 1940–1985 (mean age 36.5 $\pm$ 8.8 years; range 18–65 years). Bivariate analyses included *t*-tests and Spearman rank (rho) correlation coefficients to assess associations between anthropometrics with the number of displacement experiences and age at resettlement abroad. Participants were asked to list the number of times they were displaced, from 0 to 6 or more. Because of a skewed distribution in the number of lifetime displacement experiences, these were re-categorized into the following four groups for purposes of statistical analysis: 0, 1, 2–3 and 4 or more. This allowed for the creation of three ($k - 1$) dummy variables for the linear regression analysis, while reducing skewness and merging categories with few individuals. This re-categorization also allowed the integrity of the variable to be maintained, so that the effect of the total number of displacements (none, one, moderate, large) on linear growth could be tested. Being displaced one time served as the reference for the dummy variables, as the majority of the sample fell in this category.

Multiple regression analysis was used to assess the independent effects of the number of displacement experiences and displacement in infancy (before age 2 years) on the anthropometric variables, with age at resettlement also included in the model. Separate models were run for males and females, as preliminary analyses revealed that linear growth in females appeared to be more affected by the total number of displacements. In addition, Lao and Hmong in the sample had different geographic origins and experiences during the war (the Hmong were primarily from rural, northern Laos, while the Lao were mainly from towns along the Mekong river). While the main objective of the study was to look at the effects of displacement on linear growth and there are no studies suggesting genetic differences in height among ethnic groups from Laos, merging the two groups together here could be somewhat problematic. However, given the relatively small number of Lao in the total sample, ethnicity was not included in the regression models. Instead, a separate model was run for the Hmong sub-sample to explore whether effects seen in the total sample were representative. For the Hmong, there were no significant differences in height in those from the US and French Guiana and, thus, were pooled together here.

Age at resettlement was employed as a covariate, based on the premise that the younger a person was upon being resettled in a politically stable environment, the more years one would have to grow under better nutritional conditions. Although this is another migration experience, it was conceptualized as being qualitatively different from forced displacement related to war and was not included as such. Further, age at resettlement was adjusted and cut off at age 22 years, since most linear growth is completed by this time, even in ecologically stressed populations (Frisancho and Baker 1970; Little et al. 1983). In other words, for purposes of this study, individuals who resettled at age 23 or older were counted as having migrated at age 22 in bivariate and multivariate analyses. Age, rather than age at resettlement, was considered as a covariate because of the potential confounder of age-associated loss of stature. The effect of age was examined in post-hoc regression analyses, but this did not noticeably

Table I. Descriptive statistics for displacement and resettlement experiences ($n = 365$).

	Males ($n = 196$)	Females ($n = 169$)	Total ($n = 365$)
Displaced as an infant, before age 2 years, *n* (%)			
Yes	74 (37.8%)	36 (21.3%)	110 (30.1)
Number of times displaced, *n* (%)			
0	8 (4.1)	16 (9.5)	24 (6.6)
1	89 (45.4)	101 (59.8)	190 (52.1)
2–3	45 (23.0)	27 (16.0)	72 (19.7)
4+	54 (27.6)	25 (14.8)	79 (21.6)
Total	196 (100.0)	169 (100.0)	365 (100.0)
Age at resettlement in US or French Guiana (years)			
mean ± SD	16.3 ± 8.6	18.5 ± 10.5	17.3 ± 9.6

change the relationship between predictor and dependent variables and was therefore omitted.

RESULTS

Descriptive statistics for displacement and resettlement experiences are presented in Table I. Just over 30% of the sample reported being displaced at some point before age 2 years, although this rate was almost twice as high for males than females (37.8% vs 21.3%). The reason for the disparity is that Hmong males (the largest group in the sample) were more likely to originate from the harder hit war-zone areas in Laos. The majority of the sample (52.1%) reported being displaced just once, although many individuals reported being displaced four times or more (21.6%). Males were more likely than females to have been displaced two times or more. The mean unadjusted age at resettlement in French Guiana or the US was 17.3 ± 9.6 years.

For the anthropometric variables, descriptive statistics are presented in Table II, stratified by sex and whether one was displaced in infancy. Males and females who reported being displaced at some point in infancy had significantly smaller values for height ($p = 0.003$; $p < 0.001$, respectively) and leg length ($p = 0.001$ for both sexes). Sitting height appeared to be affected less than leg length for both sexes and was significantly different only for females ($p = 0.003$), while the sitting height ratio was significantly different only for males ($p = 0.039$).

The results of the bivariate Spearman rank correlations are shown in Tables III and IV for the total sample and Hmong sub-sample, respectively. For the total sample, the number of times one was displaced was negatively correlated with height and leg length in both sexes, although the strength of these correlations were low-to-moderate, ranging from $\rho = -0.18$ ($p < 0.05$) for height in males to -0.43 ($p < 0.01$) for height in females. The relationship between the number of times displaced and height is fairly linear, with adults who had more displacement experiences being shorter, and is further illustrated in Figure 1. However, for the Hmong sub-sample, linear growth was significantly correlated with the number of times displaced only for females.

For the total sample, leg length was more strongly correlated with the number of times displaced than was sitting height in both sexes. In fact, the number of times displaced was significantly correlated with sitting height only for females ($\rho = -0.34$; $p < 0.01$), but not for the sitting height ratio in either sex. However, for the Hmong sub-sample, sitting height appeared to be slightly more correlated than leg length with number of displacement experiences. Adjusted age at resettlement (cut-off at age 22 years) was significantly and negatively correlated with height and leg length only in males in the total sample and both sexes in the Hmong sub-sample.

The results of the linear regression analysis for the total sample are summarized in Table V. A higher number of displacements was negatively associated with linear growth for females, but not males. For example, females who were displaced four times or more had deficits in height ($\beta = -4.10$; $p = 0.003$), sitting height ($\beta = -1.63$; $p = 0.044$) and leg length ($\beta = -2.47$; $p = 0.004$) compared to those displaced just once. For males, being displaced in infancy was negatively associated with height ($\beta = -3.36$; $p = 0.002$), sitting height ($\beta = -1.26$; $p = 0.034$) and leg length ($\beta = -2.10$; $p = 0.002$). However, as was the case with the bivariate correlations, the number of times one was displaced was not associated with the sitting height ratio. Adjusted age at resettlement was negatively associated with linear growth in males, but not females. The sitting height ratio was not associated with any of the predictors in either sex. The amount of variance (R^2) explained by the variables was much higher in females than males (for example, 21.4% for female height vs 10.2% for male height).

Table II. Descriptive statistics for anthropometric variables by sex and whether one was displaced in infancy.

	n	Height (cm)	Sitting height (cm)	Leg length (cm)	SHR ([sitting height/stature] × 100)
Males					
Displaced as an infant	74	158.43 ± 7.33	85.19 ± 4.06	73.24 ± 4.14	53.78 ± 1.19
Not displaced	122	161.27 ± 5.96	86.11 ± 3.14	75.16 ± 3.92	53.41 ± 1.23
Total	196	160.19 ± 6.64	85.76 ± 3.53	74.43 ± 4.10	53.55 ± 1.22
t		−2.96	−1.77	−3.25	2.08
p-value		0.003	0.078	0.001	0.039
Females					
Displaced as an infant	36	146.24 ± 5.09	78.76 ± 2.60	67.48 ± 3.51	53.88 ± 1.28
Not displaced	133	150.49 ± 5.92	80.64 ± 3.54	69.85 ± 3.59	53.59 ± 1.33
Total	169	149.58 ± 6.00	80.24 ± 3.44	69.34 ± 3.69	53.65 ± 1.32
t		−3.93	−2.97	−3.53	1.16
p-value		<0.001	0.003	0.001	0.249

Table III. Spearman rank correlation coefficients (ρ) between displacement and resettlement experiences and anthropometric variables for all males ($n = 196$) and females ($n = 169$).

		Height	Sitting height	Leg length	Sitting height ratio (SHR)
No. of times displaced	Males	−0.18*	−0.08	−0.18*	0.11
	Females	−0.43**	−0.34**	−0.36**	0.10
Adjusted age at resettlement	Males	−0.20**	−0.16*	−0.18**	0.08
	Females	−0.05	−0.11	−0.03	−0.11

* $p < 0.05$, ** $p < 0.01$.

For the Hmong sub-sample, the results of the linear regression analysis are shown in Table VI. For Hmong females, the effects of total number of displacement on linear growth run in the same negative direction seen in the total sample, although they failed to reach statistical significance. For Hmong males, being displaced as an infant remained a negative predictor of height ($\beta = -2.82$; $p = 0.009$), sitting height ($\beta = -1.31$; $p = 0.037$) and leg length ($\beta = -1.51$; $p = 0.018$), while adjusted age at resettlement was a predictor of height and leg length only. As in the total sample, the sitting height ratio was not associated with any of the predictors in either sex. The amount of variance (R^2) explained by the variables was slightly smaller than in the total sample (17.5% for female height vs 8.8% for male height).

DISCUSSION

Linear growth retardation at the population level is often viewed as a measure of poor environmental conditions, although growth patterns under such circumstances are complex and depend on the nature and timing of the adverse environment (Tanner 1986; Cameron 2007). In a sample of Hmong and Lao refugees living in the US and French Guiana, the association between experiences related to forced migration and height and body proportions was investigated. Information on forced migration was obtained via questionnaires and included the total number of times one was displaced by war in Laos and whether one was displaced in infancy (defined as before age 2 years). In addition, information was obtained on the age one was resettled abroad.

In bivariate analyses, adults of both sexes who were displaced in infancy were significantly shorter than those not displaced during this time. Height was significantly and negatively correlated with the total number of times one was displaced in females ($\rho = -0.43$; $p < 0.01$) and males ($\rho = -0.18$; $p < 0.05$). For the Hmong sub-sample, this relationship held in the analysis for females ($\rho = -0.35$; $p < 0.01$), but not for males, indicating that ethnic differences were somewhat of a factor in this sample. For females, the strength of the correlation was fairly robust, indicating a real biological, not merely statistical, effect.

Compared to the bivariate analyses, slightly different patterns were found in the linear regression analyses when the various predictors were considered simultaneously. For males (in both the total sample and Hmong sub-sample), linear growth continued to be negatively predicted by displacement in infancy and adjusted age at resettlement abroad, but not the total number of times displaced. Leg length and height were more strongly associated with displacement in infancy than was sitting height. However, for females, only the total number of displacements was significantly and negatively associated with linear growth and this was the case only for the total sample, although not for the Hmong sub-sample. The sitting height ratio was not associated with any of the predictors in any model.

These discrepancies between the sexes and the models defy simple explanations. For example, in the bivariate analysis, the correlation between the total number of times one was displaced and height was higher for females than males. This is somewhat in contrast to previous research. Stinson (1985) found some support for the hypothesis that growth in females is buffered against harmful environmental effects, although this effect often becomes less consistent across populations from the pre-natal and infancy periods into childhood, as male children in many societies are sometimes given preferable treatment.

It is difficult to explain why this disparity exists in the current study. Traditionally, Hmong and Lao women hold less privileged positions than men (Ireson 1996), although it is not possible to claim any causality between culture and sex disparities in childhood growth here. Nutritional surveys in children from various ethnic groups in Laos have found that rates of stunting remain as high as 50% in young children, even in recent years (Phimmasone et al. 1996; Erlanger et al. 2008). In a sample of mostly ethnic Lao in Luangprabang province, Phengxay et al. (2007) found that rates of stunting were higher in boys, indicating that girls in Laos are somewhat buffered from growth faltering. Again, this is at

Table IV. Spearman rank correlation coefficients (ρ) between displacement and resettlement experiences and anthropometric variables for Hmong males ($n = 163$) and Hmong females ($n = 109$).

		Height	Sitting height	Leg length	Sitting height ratio (SHR)
No. of times displaced	Males	−0.13	−0.10	−0.09	0.01
	Females	−0.35**	−0.29**	−0.28**	0.03
Adjusted age at resettlement	Males	−0.23**	−0.13	−0.22**	0.11
	Females	−0.29**	−0.28**	−0.21**	−0.04

* $p < 0.05$, ** $p < 0.01$.

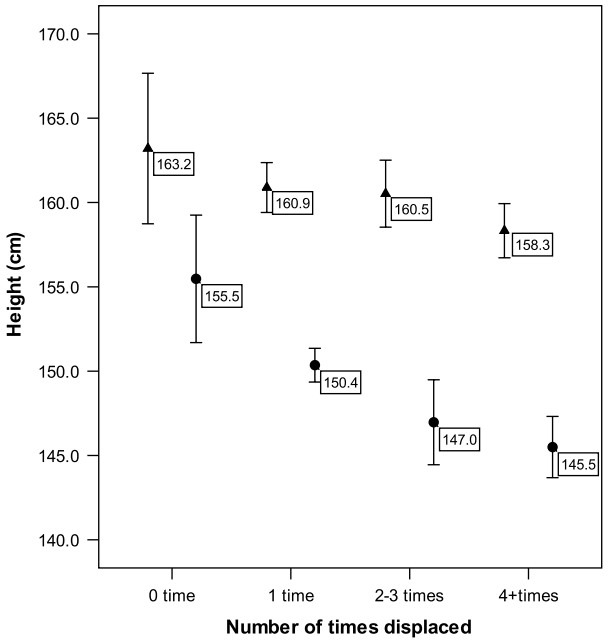

Figure 1. Means and 95% confidence intervals of height (cm) by sex and number of times displaced by war for the total sample ($n = 365$). Triangles represent males; circles represent females.

odds with the current study. It is possible that this could reflect a disparity between conditions faced by males and females during war conditions decades ago compared to more recent conditions. Alternatively, it could indicate limitations in the data collection and the small sample.

Additionally, the different models produced varying results. For example, displacement in infancy was a significant predictor of height in females only in the bivariate analysis, although not the regression model. One likely possibility for this disparity could be that few females in this sample actually reported being displaced in infancy and could be attributable to a lack of statistical power to detect a significant effect. For males, being displaced as an infant was a better predictor of height than the total number of displacement experiences, which could be indicative of the importance of the timing of refugee experiences, rather than merely the total number. Although the potential for catch-up growth exists beyond infancy, previous research has emphasized the importance of this time as a critical period for linear growth retardation (Adair 1999; Martorell 2010). Thus, a variable such as the total number of times displaced may be an imperfect, retrospective proxy, omitting critical information on the timing of conditions that could be potentially deleterious toward physical growth. However, for both sexes, the direction of the correlation was the same: in general, forced displacement was associated with deficiencies in linear growth (height, sitting height, leg length), whether it is displacement in infancy in males or the total number of times displaced in females.

Previous research has found that place of birth (war-zone vs safe-zone) was correlated with adult height and adiposity in Hmong adults, in that individuals who were born in a war-zone were shorter and had greater body fat stores than those born in safer areas (Clarkin 2008). This was viewed as being consistent with some of the predictions made by the developmental origins of adult disease hypothesis, in that small body size and greater body fat may be partial physiological adaptations in times of environmental scarcity (e.g. Barker 2004; Gluckman and Hanson 2004). However, the current study goes beyond this by exploring the effects of post-natal displacement experiences on linear growth and by including adults of Lao ethnicity in the sample.

Although other studies have found that refugee children and adolescents exhibit high rates of malnutrition and linear growth retardation (Toole and Waldman 1993; Mashal et al. 2008), it is difficult to find other studies specifically linking forced displacement experiences early in life with adult height. Although forced displacement is merely a proxy for adverse war-related experiences, it is not surprising that refugee experiences should be associated with long-term or permanent deficiencies in physical growth. Multiple biological pathways—likely occurring

Table V. Linear regression analyses for linear growth for the entire sample (Hmong and Lao).

	Height			Sitting height			Leg length			Sitting height ratio		
	β	SE	p	β	SE	p	β	SE	p	β	SE	p
Males ($n = 196$)												
Constant	164.59	1.40	<0.001***	87.37	0.76	<0.001***	77.22	0.87	<0.001***	53.08	0.27	<0.001***
Displaced 0 times	0.78	2.41	0.747	0.41	1.31	0.760	0.38	1.50	0.802	−0.01	0.46	0.989
Displaced 2–3 times	1.33	1.26	0.293	1.01	0.69	0.141	0.32	0.78	0.686	0.18	0.24	0.460
Displaced 4+times	−0.35	1.33	0.979	0.08	0.72	0.913	−0.11	0.83	0.890	0.04	0.26	0.874
Displaced as an infant	−3.36	1.09	0.002**	−1.26	0.59	0.034*	−2.10	0.68	0.002**	0.34	0.21	0.106
Adj. age at resettlement	−0.24	0.09	0.008**	−0.10	0.05	0.043*	−0.14	0.05	0.011*	0.02	0.02	0.248
R^2		0.102			0.059			0.101			0.034	
Females ($n = 169$)												
Constant	150.42	1.38	<0.001***	81.17	0.83	<0.001***	69.25	0.88	<0.001***	53.98	0.34	<0.001***
Displaced 0 times	4.99	1.61	0.002**	2.22	0.96	0.022*	2.78	1.03	0.007**	−0.30	0.40	0.447
Displaced 2–3 times	−2.69	1.26	0.035*	−1.43	0.76	0.060	−1.26	0.80	0.120	0.02	0.31	0.953
Displaced 4+times	−4.10	1.35	0.003**	−1.63	0.80	0.044*	−2.47	0.86	0.004**	0.38	0.33	0.251
Displaced as an infant	−1.83	1.23	0.140	−0.89	0.74	0.230	−0.94	0.78	0.232	0.08	0.30	0.806
Adj. age at resettlement	0.01	0.08	0.925	−0.03	0.05	0.499	0.04	0.05	0.435	−0.02	0.02	0.207
R^2		0.214			0.148			0.163			0.023	

Table VI. Linear regression analyses for linear growth for the Hmong sub-sample.

	Height			Sitting height			Leg length			Sitting height ratio		
	β	SE	P	β	SE	P	β	SE	P	β	SE	P
Males ($n = 164$)												
Constant	163.99	1.47	<0.001***	87.34	0.85	<0.001***	76.65	0.87	<0.001***	53.25	0.28	<0.001***
Displaced 0 times	−0.95	2.65	0.721	−0.18	1.53	0.905	−0.76	1.56	0.625	0.18	0.51	0.716
Displaced 2–3 times	1.62	1.32	0.223	0.74	0.76	0.335	0.88	0.78	0.261	−0.08	0.25	0.745
Displaced 4+ times	0.97	1.43	0.501	0.01	0.83	0.986	0.95	0.84	0.260	−0.33	0.27	0.229
Displaced as an infant	−2.82	1.09	0.009**	−1.31	0.62	0.037*	−1.51	0.63	0.018*	0.13	0.21	0.516
Adj. age at resettlement	−0.28	0.09	0.006**	−0.09	0.06	0.120	−0.19	0.06	0.002**	0.04	0.02	0.052
R^2		0.088			0.055			0.084			0.025	
Females ($n = 109$)												
Constant	150.40	1.58	<0.001***	81.15	0.93	<0.001***	69.24	1.02	<0.001***	53.97	0.40	<0.001***
Displaced 0 times	3.91	2.15	0.072	1.52	1.27	0.233	2.38	1.38	0.088	−0.40	0.54	0.465
Displaced 2–3 times	−0.93	1.44	0.520	−0.76	0.85	0.375	−0.17	0.93	0.855	−0.17	0.36	0.652
Displaced 4+ times	−1.86	1.56	0.235	−0.78	0.92	0.396	−1.08	1.00	0.286	0.14	0.39	0.718
Displaced as an infant	−1.47	1.26	0.247	−0.65	0.75	0.390	−0.82	0.81	0.314	0.11	0.32	0.733
Adj. age at resettlement	−0.14	0.10	0.186	−0.09	0.06	0.129	−0.04	0.07	0.508	−0.01	0.03	0.611
R^2		0.175			0.136			0.116			0.014	

simultaneously—could conceivably link forced displacement and growth faltering. For example, refugee experiences are frequently accompanied by lack of food and water, physical exhaustion and infection (Prothero 1994; Toole and Waldman 1997). During the war in Laos, persons displaced from war zone areas were often found to be starving, with protein, calorie and micronutrient deficiencies (Yang 1993: 51; Weldon 1999: 125), although many received humanitarian aid upon making it to safer areas (US Congress 1970; USAID 1976).

It is also possible that psychological stress resulting from forced displacement could play a role in growth deficiencies. Forced displacement is often accompanied by psychological stress, including post-traumatic stress disorder (PTSD) and depression (Sabin et al. 2003; Thapa and Hauff 2005; Roberts et al. 2009; Steel et al. 2009). Although psychological stress has not been associated directly with growth failure in refugee children, it has been in other cases of prolonged adversity, such as in instances of psychosocial dwarfism and in some groups of orphans (Saenger et al. 1977; Gunnar et al. 2001). While the precise mechanisms are not fully understood, chronic activation of the stress response via the hypothalamus-pituitary-adrenal (HPA) axis may lead to the inhibition of growth hormone, insulin-like growth factor (IGF-1) and/or thyroxine stimulating hormone (Burguera et al. 1990; Chrousos and Gold 1992; Gohlke et al. 2004). Psychological stress during war, acting in concert with nutritional stress, has been cited as a possible cause in delay of menarche and sexual maturation in the Second World War, the Korean War and the wars in the former Yugoslavia (van Noord and Kaaks 1991; Tahirović 1998; Prebeg and Bralić 2000; Hwang et al. 2003). However, the relationship between stress and maturation is complex and contingent upon the interaction between individual children and different environmental stressors (Belsky et al. 1991). For example, Ellis et al. (2011) found that in Wisconsin children with higher stress reactivity, which the authors termed 'biological sensitivity to context', combined with lower quality relationships with their parents had faster pubertal tempo and earlier pubertal timing. Unfortunately, surveys of Hmong and Lao mental health, such as the prevalence of PTSD and its correlates to war experiences, are lacking. Nor is it possible in the current study to separate which stressors could be involved in affecting linear growth.

Anthropometric data on Laotian adults are difficult to find, although females in the current sample were not noticeably taller than those who remained in Laos (149.6 cm vs 147.0–148.5 cm; data from Khamhoung et al. 2000). This was somewhat unexpected, as Laos remains one of the least developed countries in Asia (UNICEF 2008), while individuals in the current study were refugees and spent more years living and growing in presumably better environmental conditions. In comparison, women in Hanoi, Vietnam were 156.4 cm in 1997–1998 (Hop 2003), while Cambodian women in 2000 were 152.6–153.5 cm (deWalque 2006). Future studies might explore what effects war conditions and forced displacement have had on the growth and development of non-refugees who remained in Southeast Asia.

In comparison to total height, the effects of forced migration on body proportions, including the sitting height ratio, were equivocal. It was expected that leg length would be more affected by forced displacement than sitting height, leading to a higher sitting height ratio (SHR). In bivariate analyses (*t*-tests), the SHR was significantly higher only for males who were displaced in infancy. This was due to the fact that leg length was shorter in displaced males, while sitting heights did not differ significantly. For females, both leg length and sitting height were significantly shorter, leading to similar SHR in displaced and non-displaced persons.

In the bivariate correlations for the entire sample, the total number of times one was displaced was slightly more correlated with leg length than sitting height for males ($\rho = -0.18$ vs -0.08, respectively) and females ($\rho = -0.36$ vs -0.34, respectively), but correlations were not significant for the SHR in either sex. However, for Hmong females, the total number of times displaced correlated slightly better with sitting height than leg length. In the linear

regression analyses, SHR was not significantly predicted by any independent variable in any model.

Thus, in the current study displacement in infancy and total number of displacements provide only weak support for the premise that leg length and the SHR are more sensitive to environmental conditions early in life than sitting height (Bogin et al. 2002; Li et al. 2007; Padez et al. 2009). The lack of consistent associations between refugee experiences and body proportions may be due to a number of limitations with the current study. For example, leg length (and thus SHR) may be prone to error, as it is a derived measurement calculated as the difference between standing and sitting heights, which are both subject to measurement error. Also, leg length and sitting height vary in relation to the timing of peak growth velocity, while the timing of displacement experiences in the current study was not specified beyond those which occurred before age 2 years. For example, leg length growth is faster and thus more sensitive to environmental disturbances in early childhood and ceases at an earlier age than sitting height growth (Dangour et al. 2002). In contrast, sitting height growth appears to be faster than leg growth after age 5 years and before puberty. Further, leg length and sitting height may be affected differently by various environmental stressors. In the British 1946 national cohort (Wadsworth et al. 2002), leg length was more sensitive to socioeconomic conditions and nutrition before age 5 years, while trunk length was more sensitive to serious illness and chronic emotional disturbance (parental separation). In future studies, use of forced displacement as a variable to test against anthropometrics or potentially other health data should include more specific information on the age at which they occurred rather than solely the number of times displaced.

The current study has other limitations as well. By using a non-random convenience sample, as well as retrospective data on displacement experiences obtained from questionnaires, it cannot be determined that the associations between forced displacement and deficits in growth are causally related. Another limitation is the fact that individuals were measured in a number of settings under field conditions in French Guiana and the US, from individual homes to community gatherings. By not conducting all measures in a central location, this creates the possibility of measurement variability. However, an attempt was made to create consistent conditions in all settings by having the PI conduct all anthropometrics with the same equipment. This study is also limited by the potential for recall bias on the part of participants, particularly given the length of time that passed between some life events and the time of the questionnaire. Additionally, using the number of times displaced as a predictor variable is not without problems. While the number of times displaced is easily quantifiable, it is also true that displacement experiences are heterogeneous in terms of severity, duration, distance travelled and whether or not there was adequate preparation time prior to fleeing. Nor was the specific timing of refugee experiences ascertained (except for those occurring before age 2 years). Such information would have strengthened the current analysis.

Nonetheless, it seems logical that a greater number of displacement experiences, given their associated risks, would be correlated with long-term effects on height, other anthropometrics and possibly other biological and health outcomes. In future research, attempts to test whether forced displacement is associated with biological variables in other populations should better account for the number, nature, timing and perhaps even duration between specific displacement events.

CONCLUSION

In a study of adult Hmong and Lao refugees living in the US and French Guiana, it was observed in bivariate and multivariate analyses that being displaced in infancy was negatively associated with adult height, sitting height and leg length in males. This was true of the entire sample and of the Hmong sub-sample. For females, the total number of times one was displaced was negatively associated with adult height, sitting height and leg length in a linear regression analysis for the total sample, although this relationship held for the Hmong sub-sample only in bivariate correlations. However, the sitting height ratio was not associated with either displacement variable in any analysis.

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