# PATTERNS OF BLOOD PRESSURE RESPONSE IN MIGRANT AND NONMIGRANT TOKELAUANS

## III: RESPONSE IN TOKELAUAN CHILDREN

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## Abstract

Although evidence is accumulating that the tendency to elevated blood pressure (BP) begins in childhood, little is known about the impact of environmental factors in this age group, especially in the cross-cultural context. The effect of major environmental changes on the distribution of BP can be evaluated by measuring the response of BP in children to migration. Here we report on the distribution of BP response in Tokelauan children who migrated to New Zealand (NZ) and the association of response with other physiological and socio-cultural factors.

BP and other cardiovascular risk factors were initially measured on premigrant Tokelauan children, living on their home atolls, and then measured several years later on nonmigrants living in Tokelau or on migrants living in NZ. BP response was computed for both migrant and nonmigrant children, and the association with physiological and socio-cultural effects of migration were evaluated by regression analysis.

The major component of BP response in both migrants and nonmigrants is associated with obesity. However, both groups differ significantly from the premigrant children, in the association between BP and obesity. No other measured physiological or socio-cultural variable, including length of residence in NZ, made a major contribution to response, although there are small significant associations between response and serum lipids for nonmigrants, and urinary sodium excretion for migrant boys.


## Introduction

The rapid environmental changes accompanying migration provide opportunity to assess the effects of environmental stress on blood pressure (BP). Evidence is accumulating that the tendency to elevated BP begins and is detectable in childhood[1]. Unfortunately, few studies of childhood BP exist, especially in the cross-cultural context. The Tokelau Island Migrant Study provides a unique study of children migrating from a traditional, non-acculturated society, to an acculturated setting. The children were first seen in 1971 on the Polynesian home atolls, and follow-up studies were done on the migrants in 1975-1977 in New Zealand, and on the nonmigrants in 1976 in Tokelau. Since both the children and their parents have been observed before and after migration from a traditional Polynesian society to an urbanized Western one, the study has a "quasi-experimental" design. The nonmigrants form a natural control group against which can be evaluated the response of BP to the major environmental change caused by migration.

In order to assess the effects of migration on BP, a measure of response to environmental change is required. To be useful, the BP response measure should permit discrimination between postmigration changes in BP that are attributable solely to an altered distribution of relevant concomitants, such as increased age and weight, and BP changes that arise because of the introduction of a new factor or a changed relationship with an established concomitant. Previously, we developed such a measure[2] and applied the technique to adult Tokelauans. BP response was determined in the postmigrant environment as the difference between the observed BP and the value predicted from the postmigrant values of known concomitants of BP. In this paper, we use this procedure to compute BP response for Tokelauan children, and then evaluate the relationship between BP response and a set of socio-cultural and physiological variables.

## Study Design

The Tokelau Island Migrant Study was initiated in 1967/68 to study the effects of migration to New Zealand on the prevalence of hypertension and other risk factors for cardiovascular disease in the Tokelau population. The main objective has been to investigate the interaction between environmental change, the accumulation of socio-cultural stress, and the subsequent increase in BP, obesity, and other cardiovascular disease risk factors in the migrants.

A medical survey, which included children age four years and up, was carried out on the atolls in 1971. This defines the premigrant population. Data was collected in NZ in 1975 (the migrant population) and in Tokelau in 1976 (the nonmigrant population). The study design and methodology have been reported in detail elsewhere [3-5]. The premigrant survey demonstrated that individuals who would subsequently migrate and those who would not were similar with respect to the values of cardiovascular risk variables[6].

Tokelauan society now comprises about 4000 individuals split into two components. The migrant population, which comprises about 60% of the total, is distributed mainly in three centers on the North Island of New Zealand. The remaining nonmigrant component is distributed on the three homeland atolls, with Fakaofo having the largest population (42% of the nonmigrants), Nukunonu the smallest (24%), and Atafu the remainder (34%)[7].

In two previous papers[2,8], we explored the relationship between migration and BP response in Tokelauans who were 18 years and older. For the present study, we examine children between 5 and 18 years of age. This differs slightly from some of the previous studies of Tokelauan children, where the upper age limit was 15 years.

Previous work suggested that, in the premigration time period, the relationship between BP and age differed for younger and older children, with a distinct break at about age 9 years[4]. With the older teenagers included, we found break points at 10.2 years for boys and 10.3 years for girls. In the remainder of the paper, the younger children are referred to as juveniles, and the older ones as adolescents.

All statistical analyses in this paper were done using the "S" statistical package[9].

## Method

In a previous paper[2], we defined the response of BP to environmental change in terms of residuals from a regression. It is the component of change in BP which cannot be predicted from the change in distribution, in the new environment, of a set of concomitant variables. We showed that when a population has been sampled cross-sectionally over time, BP response recovers much of the information about factors underlying changes in BP that could be obtained from a longitudinal study[2].

To obtain the response variable for adults, we regressed baseline BP on the concomitants listed in Table 1, measured in the baseline time period. The resulting regression equation was used with the concomitants measured in the follow-up time period, to obtain a prediction for BP. Deviations from this prediction were used as the response variable. As indicated in Table 1, we followed a similar method for the children, using seven concomitants to define the baseline relationship. Serum cholesterol was not measured for many children, and so was not used in this analysis.

## Results

The baseline regression equation was determined by regressing BP on the concomitants, for each sex-age group, allowing for variation in slope between atolls. All subsets regression was used to determine a subset of regressors that adequately described the data.

The contributions to $R^2$, partialled in the order given, are summarized for this regression in Table 2. For juvenile boys, the significant terms were atoll of origin and height. However, the concomitants explain very little of the variation in BP. For adolescent boys, atoll of origin, weight, and age are significant concomitants with body mass index being significant for Nukunonu boys only.

For juvenile girls, the variables selected were atoll of origin, weight, and age. For adolescent girls, the variables selected were body mass index, age, and for Fakaofo girls, weight and body fat index.

The regression coefficients obtained from the premigrant (baseline) time period were used to predict postmigrant BP from the postmigrant values of the concomitants. The response variable was defined as the difference between this predicted value, and the observed BP. Table 3 summarizes mean response for each sex-age-survey group. The patterns for boys and girls are very similar. Response is negative for both nonmigrants and migrants, except for SBP response in juveniles. SBP response in juveniles and DBP response in adolescents is significantly greater in migrants, while DBP response in juveniles and SBP response in adolescents do not differ significantly between environments. Contrary to expectations, adolescent nonmigrant girls exhibit a higher SBP response than migrants, although the difference is not statistically significant.

We again used all subsets regression to choose a subset of these same concomitants that were most strongly associated with BP response, in both the migrants and nonmigrants. Table 4 summarizes the contributions to $R^2$ of response made by these concomitants. For juvenile boys in both environments, there is no significant association between BP response and any of the original concomitants. For nonmigrant adolescent boys, body mass and age had the strongest association, while for migrants, height was also significant. For juvenile girls in both survey groups, body mass and age were significant. For adolescent girls, weight, body fat index were significant for both survey groups. In addition, age was significant for nonmigrants and height for migrants.

We next investigated the relationship between BP response and various physiological variables. Serum uric acid (SUA), urinary potassium (UK) and urinary sodium (UNA) were measured on most of the children. Values of serum cholesterol, high density lipoprotein (HDL) and serum triglycerides, were also available for a small subset of each survey group. A small number of significant correlations between these variables and BP response were found and these are summarized in Table 5. The most consistent correlations were between triglycerides and BP response for nonmigrants, and between cholesterol and DBP response for adolescent girls in both environments.

Cholesterol, triglycerides and HDL could not be used for a multiple regression analysis, because of the small number of observations. The results of a multiple regression using SUA, UNA, UK, and UNA/UK are summarized in Table 6. The total contribution to $R^2$ never exceeds 9%. However, UNA does contribute significantly to $R^2$ for DBP response in migrant boys.

We also investigated the relationship between BP response and a small number of socio-cultural variables. These are listed in Table 7. The total number in the household was negatively correlated with DBP response in nonmigrant juvenile girls. Length of time in NZ was negatively correlated with SBP response of juvenile girls, and DBP response for adolescent girls.

## Discussion

Since major environmental changes are often associated with changes in growth patterns, it could be supposed that migrant children would exhibit a more marked change in BP than migrant adults. However, when this hypothesis was evaluated in the Tokelauan case by comparing BP response for children and adults, it was not borne out. While BP response in adults is negative, except in migrant men[2], there is an appreciable difference between migrants and nonmigrants. Children also tend to exhibit a negative response, but the pattern of BP response, given in Table 3, is not clear cut. Juvenile migrants have a higher response than juvenile nonmigrants for SBP, and virtually identical response for DBP. Adolescent migrants have higher response than nonmigrants, except for female SBP, for which the nonmigrants are higher. Overall, the difference between nonmigrant and migrant response is smaller for Tokelauan children than for adults, in every category except juvenile girls' SBP. This suggests that, during the time period of this study, the BP response to major environmental change has been smaller in children than in adults.

For the premigrant children, the contributions to $R^2$ of BP by the original concomitants is generally under 20%. This is about half the value found for premigrant adults. The goal of the response variable approach is to partition the variance of the postmigration BP into a component associated solely with the change in the values of the concomitants, and a component related to other factors in the new environment. The small predictive value of the original concomitants in the premigrant time period suggests that changes in the postmigration time period cannot simply be ascribed to changes in the concomitants.

For the children, the sex differences were sufficiently large that it was necessary to group by sex. By contrast, in premigrant adults, sex does not enter the regression equation for SBP and enters only as an interaction with the cubic age term for DBP.

For some sex-age groups of children, the concomitants are more strongly associated with BP response than with raw BP. For the adults, however, the concomitants are less strongly associated with response. This is because in adults a major component of BP, associated with obesity, is largely predicted by the premigrant equation. The reversal of this relationship in children suggests that the relationship between obesity and BP in the premigrant children is not typical of the relationship in postmigrant children. The distribution of body mass index with age for premigrant and nonmigrant girls in both age groups and for juvenile boys are almost identical, while migrants have significantly greater body mass. However, the regression of raw BP on body mass index are parallel for premigrants and nonmigrants in these sex-age groups only for juvenile SBP. Regression lines are parallel for nonmigrants and migrants however, for juvenile boys' and girls' DBP, and for adolescent girls' SBP. For adolescent boys, the body mass of nonmigrants is intermediate between that of premigrants and of migrants, and the regression slopes in the three groups differ significantly. Thus evidence suggests that there is an interaction between weight and some unknown concomitant in the follow-up time period.

None of the physiological, socio-cultural, and medical variables are strongly associated with BP response for the children, although there is some suggestion that UNA and the ratio of UNA/UK is significantly correlated with DBP response for migrant boys, and that length of stay in New Zealand is negatively correlated with BP response for migrant girls. There is also an indication that serum lipid levels are associated with BP response in nonmigrant children, but the number of observations is small.

In the Bogalusa Children's Study[1], Berenson found that the major associates of raw BP in children 5 to 14 years of age were height and ponderosity (weight/height$^3$). For the Tokelau premigrant children, Beaglehole et al[4] found a relationship between raw BP and obesity only for adolescent SBP. However, by comparing the difference in age-standardized SBP across the nonmigrant and migrant environments, with the age and weight standardized values, they concluded that 30-50% of the difference in SBP between the two postmigration environments could be accounted for by differences in obesity in the two environments[10].

Using the response variable approach, we also found, for both children and adults, that obesity is the major correlate of response of BP to environmental change[8]. However, the differences in the relationship between response and obesity in the postmigrant environments, and between raw BP and obesity in all three environments, suggests that additional factors may also be involved in both the migrant and nonmigrant environments.

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**TABLE 1: Concomitants of BP used to define response in Tokelauan adults and children.**

| | ADULTS | CHILDREN |
|---|---|---|
| sex | X | grouped by sex |
| atoll | X | X |
| age | cubic | linear within age groups |
| height | X | X |
| weight | X | X |
| body mass (wt/ht$^2$) | X | X |
| fat index | X | X |
| cholesterol | X | |

X indicates a variable used as a concomitant in defining BP response.

**TABLE 1: Contributions by concomitants to $R^2$ of raw BP in premigrant Tokelauan children.**

| | | atoll | ht | wt | quet | fat | age | total |
|---|---|---|---|---|---|---|---|---|
| boys <10.2 | sbp | 3.2 | 1.6 | | | | | 4.8* |
| | dbp | 0.5 | 1.5 | | | | | 2.0 |
| >10.2 | sbp | 1.3 | | 20.2** | 3.9*n | | 1.9 | 27.3** |
| | dbp | 5.2** | | 0.3 | 2.1 | | 0.2 | 7.8* |
| girls<10.3 | sbp | 3.7* | | 15.7** | | | 0.5 | 19.9* |
| | dbp | 0.5 | | 9.3** | | | 0.7 | 10.5** |
| >10.3 | sbp | | | 0.6f | 11.4** | 5.4*f | 2.1 | 19.5** |
| | dbp | | | 7.4**f | 1.3 | 1.3 | 2.0 | 12.0 |

* .01<p<.05    f Fakaofo only

** p<.01    n Nukunonu only

**TABLE 3: Mean BP response by age group and sex for migrant and nonmigrant Tokelauan children.**

| | N | nonmigrant response | N | migrant response | difference in response |
|---|---|---|---|---|---|
| boys <10.2 sbp | 190 | 8.4 | 132 | 2.2 | 6.2** |
| dbp | | -8.8 | | -8.8 | 0.0 |
| >10.2 sbp | 199 | -5.7 | 156 | -6.4 | 0.7 |
| dbp | | -5.7 | | -11.4 | 5.7** |
| girls<10.3 sbp | 238 | 7.9 | 139 | 3.0 | 4.9** |
| dbp | | -4.5 | | -4.3 | -0.2 |
| >10.3 sbp | 112 | -7.5 | 106 | -5.2 | -2.3 |
| dbp | | -5.7 | | -9.2 | 3.5* |

* .01<p<.05

** p<.01

**TABLE 4: Contributions by concomitants to $R^2$ of BP response in postmigrant Tokelauan children.**

NONMIGRANTS

| | | atoll | ht | wt | quet | fat | age | total |
|---|---|---|---|---|---|---|---|---|
| boys <10.2 | sbp | | | 0.2 | | 9.1**f | 3.2*Δ | 12.5** |
| | dbp | 0.2n | | 4.3*f | 2.7nΔ | | | 7.2* |
| >10.2 | sbp | 2.4n | | | 8.5**nΔ | 1.9 | | 12.8** |
| | dbp | | 1.3 | | 3.8**f | | 16.7**aΔ | 21.8** |
| girls<10.3 | sbp | | | | 27.1**f | | 9.4**Δ | 36.5** |
| | dbp | 15.4**f | | | | | 7.5**nfΔ | 22.9** |
| >10.3 | sbp | | | 11.8**fΔ | | 29.6**f | 3.9** | 45.3** |
| | dbp | | | 0.4f | | 18.8** | 16.0*fn | 35.2** |

MIGRANTS

| | | atoll | ht | wt | quet | fat | age | total |
|---|---|---|---|---|---|---|---|---|
| boys <10.2 | sbp | | 2.7*fΔ | | 5.5**f | | | 8.2** |
| | dbp | | | | 2.0 | | 4.0*nfΔ | 6.0* |
| >10.2 | sbp | 6.7** | 3.1**n | 19.2**nΔ | | | | 29.0** |
| | dbp | | 2.3*fn | 13.4** | | | 3.0**fΔ | 18.7** |
| girls<10.3 | sbp | | | | 15.8** | | 3.5** | 19.3** |
| | dbp | | | | 5.7** | | | 5.7** |
| >10.3 | sbp | | 1.7 | 9.4**fΔ | | 42.0** | | 53.1** |
| | dbp | | 14.8**f | 9.1*fn | | 10.3**f | | 34.2** |

* .01<p<.05 — f Fakaofo only

** p<.01 — n Nukunonu only

Δ negative partial — a age by atoll

**TABLE 5: Significant correlations of BP response with physiological variables for migrant and nonmigrant Tokelauan children.**

NONMIGRANTS

| | sua | urea N | chol | hdl | trig | uk | ana | una/uk |
|---|---|---|---|---|---|---|---|---|
| boys <10.2 sbp | | | | | .31* | | | |
| dbp | | | | -.23* | | | | |
| >10.2 dbp | .28** | | | | | | | |
| girls <10.3 sbp | | | | | .31* | | | |
| >10.3 sbp | | | | | .27* | | | |
| dbp | | | .29* | | | | | |

MIGRANTS

| | sua | urea N | chol | hdl | trig | uk | ana | una/uk |
|---|---|---|---|---|---|---|---|---|
| boys >10.2 sbp | -.21** | | | | | | | |
| dbp | | | -.18* | | | | | .20* |
| girls>10.3 dbp | | | .20* | | | | | |

* .01<p<.05
** p<.01

**TABLE 6: Contributions by physiological variables to $R^2$ of BP response partialled in the order given**

NONMIGRANTS

| | | sua | uk | una | una/uk | total |
|---|---|---|---|---|---|---|
| boys <10.2 | sbp | 0.2 | 0.5 | 1.2 | 0.1 | 2.0 |
| | dbp | 0.2 | 2.2 | 2.5 | 0.4 | 5.3 |
| >10.2 | sbp | 1.7 | 0.0 | 0.1 | 0.3 | 2.1 |
| | dbp | 7.8** | 0.6 | 0.0 | 0.3 | 8.7 |
| girls<10.3 | sbp | 1.7 | 0.1 | 1.0 | 0.3 | 3.1 |
| | dbp | 0.0 | 0.2 | 0.0 | 0.2 | 0.4 |
| >10.3 | sbp | 2.1 | 3.0 | 0.0 | 0.9 | 6.0 |
| | dbp | 0.4 | 0.5 | 1.4 | 0.7 | 3.0 |

MIGRANTS

| | | sua | uk | una | una/uk | total |
|---|---|---|---|---|---|---|
| boys <10.2 | sbp | 0.0 | 0.1 | 0.1 | 0.0 | 0.2 |
| | dbp | 1.4 | 1.1 | 2.4* | 3.5* | 8.4 |
| >10.2 | sbp | 3.0* | 0.1 | 0.2 | 0.1 | 3.4 |
| | dbp | 3.1 | 0.2 | 3.5* | 1.0 | 7.8 |
| girls<10.3 | sbp | 0.0 | 0.3 | 0.4 | 0.1 | 0.7 |
| | dbp | 0.0 | 0.2 | 0.0 | 0.4 | 0.6 |
| >10.3 | sbp | 2.0 | 0.5 | 0.0 | 2.2 | 4.7 |
| | dbp | 1.0 | 0.0 | 2.9 | 0.1 | 4.0 |

* $.01<p<.05$

** $p<.01$