American Journal of Physical Anthropology

The influence of variation in parental height dimorphism on same-sex parent-offspring height differences

Journal:	*American Journal of Physical Anthropology*
Manuscript ID	AJPA-2017-00014.R1
Wiley - Manuscript type:	Brief Communication
Date Submitted by the Author:	n/a
Complete List of Authors:	Floyd, Bruce; University of Auckland, Anthropology
Key Words:	anthropology, stature, developmental plasticity, intergenerational
Subfield: Please select your first choice in the first field.:	Human biology [living humans; behavior, ecology, physiology, anatomy], Theory

Brief Communication

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This research was partially supported by UARC grants 3601710 / 9211 & 3602481 / 9211.

ABSTRACT

Objective: This study evaluates how adjusting for parental height dimorphism influences height differences among parents and same-sex offspring distinguished by parents' early backgrounds.

Participants and Methods: Regression analyses using data from independent groups of Taiwanese families, 56 with sons and 51 with daughters, evaluate how adjusting for parental height dimorphism influences same-sex parent-offspring height differences among families grouped by grandfathers' occupations into three status categories reflecting good to relatively poor early parental environments.

Results: Parental height dimorphism was statistically significantly associated with same-sex parent-offspring height differences (father-son: mean $\Delta = 3.88$ cm, $\beta = -71.47 \pm 11.49$ SE, $t = -6.22$, $P \leq 0.0005$; mother-daughter: mean $\Delta = 4.15$ cm, $\beta = 80.46 \pm 18.52$ SE, $t = 4.35$, $P \leq 0.0005$). Adjusted mean father-son differences increased significantly across grandfathers' occupation categories (Privileged, $\Delta = 0.60$, Business, $\Delta = 4.06$, Farming & Labor, $\Delta = 5.28$; $P = 0.011$). Mother-daughter differences were substantial, from 3.33 cm to 5.06 cm, but did not differ significantly across occupational categories ($P = 0.63$).

Discussion: Adjustments here for variation in parent height dimorphism did not alter original interpretations that while female growth may be more canalized, it is similarly capable of responding to improvements in developmental contexts. Patterns of same-sex parent-offspring height differences across grandfathers' occupational categories remain best accounted for by Taiwan's rapidly expanding economy, substantial income equity and reductions in biases favoring sons over daughters. Adjustment for sub-group variation in parental height dimorphism should be considered in similar studies in the future.

INTRODUCTION

This study evaluates the extent to which adjusting for differences in parental height dimorphism influences mean height differences among parents and same-sex offspring distinguished by parents' early backgrounds. It then considers whether such adjustments alter interpretations of female skeletal growth canalization as presented in a recent, closely related, article (Floyd, 2016). Do we anticipate that when developmental environments rapidly improve within families across generations that father-son height differences are routinely greater than mother-daughter differences because of greater intrinsic male sensitivity / greater female growth canalization as argued by Bielicki and Charzewski (1977)? Or do we anticipate that if female growth is more canalized, their skeletal growth is less likely to depart from their genetically influenced course and more likely to return quickly following physiological stress (Tanner, 1962)? In the latter case, female growth may, on average, be more "buffered" than male growth in relatively stressful settings but equally capable of responding when developmental settings improve. Stinson (1985) points out that judging between these contradictory interpretations is often difficult because of confounding by unaccounted for variation in cultural beliefs and actions that bias parental care.

Floyd (2016) takes advantage of notable intergenerational declines in gender bias against female offspring (Floyd, 2003; Freedman et al., 1994a, 1994b; Lin, 2009) and well-documented rapid, but relatively equitable, economic growth and improvements in public health beginning in the 1960s (Dessus et al. 1995; Fei et al., 1979; Galenson, 1979; Hermalin et al. 1994; Hou, 1981; Liu, 1980; Tsai, 1987) to assess which of the alternatives described above is more plausible. Differences between Taiwanese parents and their young adult offspring of the same sex were considered in two independent groups, 56 families with father-son pairs and 51 families with

mother-daughter pairs, each categorized by family background when parents were very young using grandfather's occupation. Comparisons within the parental generation are consistent with ethnographic evidence of male-biased resource allocation, but also suggest that female growth was better buffered against physiological stressors (Floyd, 2016). Same-sex parent-offspring height differences were consistent with patterns anticipated based upon familial backgrounds and reductions in gender bias. Father-son differences were smallest when fathers grew up in privileged backgrounds and increased significantly as fathers' early backgrounds became poorer. Mean mother-daughter differences across maternal grandfathers' occupational categories did not show the same marked trend, but overall mean height difference were substantial, and modestly greater than for males. This is consistent with the view that mothers in well-off families did not receive the same level of care or attention as fathers in similar settings, but mothers' heights were not reduced as much in poor families when compared with their male counterparts. Evidence also suggests that substantial declines in gender bias and improvements in living conditions influenced growth in male and female offspring in similar ways; males were not intrinsically more capable of responding to improving conditions.

Parental height dimorphism was not, however, included as a covariate in this recent study. Such unaccounted for differences in parental height dimorphism among sub-groups could, in principle, influence interpretations of intergenerational height differences in this and other studies (Bielicki and Charzewski, 1977; Kaur and Singh, 1981; Krzyzanowska, 2007; Miller, 1961; Miller, 1970). Offspring height reflects biparental genetic contributions interacting within socially-mediated developmental contexts that influence risks of pre- and postnatal stressors and post-natal skeletal stunting (Lasker and Mascie-Taylor, 1996; Bogin, 1999). In settings where offspring's early environments tend to be better than those of their parents, as with families in

this recent study, offspring tend to be taller than their parents of the same sex. How much taller, though, is likely to be partially influenced by the height of the opposite sex parent because of their genetic contributions that influence their offspring's height (Solomon et al., 1983) (see Table 1).

********** Table 1 **********

Average adult male height exceeds female height in all human populations by an average ratio of about 1.04 to 1.11 (Gustafsson and Lindenfors, 2004; Holden and Mace, 1999). In families where parent height differences are greater than average for their particular group, mothers are relatively short compared to their husbands. Secular increases in sons' heights relative to their fathers' heights will, therefore, tend to be smaller than average in so far as maternal shortness reflects genetic and developmental influences transmitted to sons. Daughters' height gains relative to their mothers will tend to be greater than average in these families to the extent that they reflect genetic influences from relatively tall fathers. In families where father-mother height differences are less than average, opposite trends will be evident for similar underlying reasons. This argued predictability, if demonstrated, permits same-sex parent-offspring height differences among groups to be adjusted for so that comparisons are not confounded by group level differences in parental height dimorphism. For example, if families within a particular sub-group who have higher than average levels of parental height dimorphism are compared to families in another group with an average level of dimorphism, adjustments for parental dimorphism are anticipated to increase father-son differences and decrease mother-daughter differences in the sub-group relative to the other group.

If we apply these adjustments here, do participating Taiwanese families defined by paternal or maternal grandfather's occupational categories differ, on average, in levels of parental height

dimorphism and, if so, do these differences influence outcomes in anticipated ways? Do these changes alter previous interpretations of parent-offspring height differences related to familial backgrounds and gender bias?

PARTICIPANTS AND METHODS

Anthropometric and family background information used in the present study were obtained from mothers, fathers and their oldest recruited offspring in 107 Taiwanese families interviewed and measured by the author. Fifty six of these families were represented by a son while 51 families were represented by a daughter. Details of recruitment and measurement procedures are reported elsewhere (Floyd, 2007, 2008). The University of Auckland Human Participants Ethics Committee approved the research protocol on both occasions and informed consent was obtained from all participants. As in previous reports, parents' heights were adjusted for sex-specific aging effects using the curvilinear adjustments proposed by Cline et al. (1989) based upon data from a mixed longitudinal study of aging.

As described more fully in Floyd (2016), developmental circumstances of focal parents as young children were characterized in terms of their own fathers' occupations based upon information about social class structure in Taiwan in years surrounding parents' births (Wang, 2002). The earliest job reported for a grandfather while their son or daughter (father or mother in the present study) were growing up was used. The "Privileged" category included military officers, middle managers to heads of state run enterprises, public servants, government officials, one medical doctor and a dentist. The "business" category was heterogeneous, though as anticipated typically less well-off judging from formal education and descriptions of family circumstances when parents were young. The "farming and labor" category included grandfathers in farming families who owned their own land as well as a smaller number who

were tenant farmers and five grandfathers who were laborers. Although land-reforms occurred in the 1950s in Taiwan, most new land owners experienced only small economic gains early on (Wang 2002). Young adult offspring in participating families typically experienced much better circumstances than their parents when very young based upon details collected by the author. These experiences are consistent with major changes in health care, housing, sanitation, and diet documented in Taiwan in the years surrounding their births (see Floyd, 2016 for further discussion from multiple sources).

I began the present study by evaluating differences in parental height dimorphism across paternal or maternal grandfathers' occupational categories for independent groups of same-sex parent-offspring pairs. Following this I used regression analyses to examine whether parental height dimorphism ratios were statistically significantly associated with parent-offspring height differences as predicted and whether adjustments to parent-offspring height differences across paternal or maternal grandfathers' occupational categories influenced original interpretations.

Parental height dimorphism is represented in this study by the ratio of father's height divided by mother's height. Preliminary analyses also used the difference between father's and mother's height to represent parental dimorphism, though Solomon et al. (1983) suggest that a ratio is statistically preferable. Results of these analyses were virtually the same as those reported below. All descriptive and inferential statistical tests in this study were accomplished using SYSTAT 10. Assumptions of normality and equivalent error variance in analyses were checked through examination of residuals on predicted values as well as probability plots.

RESULTS & DISCUSSION

Figure 1 shows the patterns of difference in father-mother height ratios, overall for the families with father-son pairs or mother-daughter pairs and within groups characterized by

paternal or maternal grandfather's occupational categories. Distributions of parental height dimorphism are similar in families with sons and daughters, though greater differences in average parental height dimorphism are evident across occupational categories. These differences in parental height ratios are not, however, statistically significant for either father-son ($F_{2, 53} = 0.83$, $P = 0.44$) or mother-daughter pairs ($F_{2, 48} = 2.10$, $P = 0.13$).

********** Fig. 1 **********

As a covariate in heteroscedastic-consistent regression models that include paternal (Table 2) or maternal (Table 3) grandfathers' occupational categories, parent height dimorphism was statistically significantly associated with same-sex parent-offspring height differences (father-son: $n = 56$, mean $\Delta = 3.88$ cm, $\beta = -71.47 \pm 11.49$ SE, $t = -6.22$, $P \leq 0.0005$; mother-daughter: $n = 51$, mean $\Delta = 4.15$ cm, $\beta = 80.46 \pm 18.52$ SE, $t = 4.35$, $P \leq 0.0005$). These similar, statistically and biologically significant influences are consistent with initial expectations. The slope coefficients of families with either father-son pairs or mother-daughter pairs are even more similar when only the covariate, parental height dimorphism, is included in the regression model (see Table 2 and 3). Inclusion of this covariate predictably alters the extent of mean parent-offspring height differences across paternal or maternal grandfathers' occupational categories in the two groups of families, but not in such a way as to alter original interpretations (Floyd, 2016) as described below.

********** Table 2 **********

********** Table 3 **********

As shown in Figure 1, father-son pairs whose grandfathers were from privileged backgrounds have the highest mean level of parental dimorphism (1.096 ± 0.009 SE). This compares to an average level of dimorphism for all father-son pairs of 1.082 ± 0.007 SE. Adjustments for

dimorphism increased the average father-son difference within this "Privileged" sub-group by a total of 0.96 cm, from -0.36 to 0.60 cm (see Fig. 2). Father-son pairs in the business category, whose parental dimorphism (1.086 ± 0.011 SE) is modestly greater than the average, have only a small (0.25 cm) adjusted increase in mean father-son difference (3.81 to 4.06 cm). Those pairs where grandfathers were involved in farming and labor had the lowest average level of parental height dimorphism (1.072 ± 0.012 SE) so the adjusted father-son height difference decreased by 0.70 cm (5.98 to 5.28 cm). Despite attenuation, the trend of increasing height difference across these grandparental categories hypothesized in the original study is sustained here (P = 0.011).

********** Fig. 2 **********

Adjusted mean mother-daughter height differences across grandfathers' background categories shown in Fig. 3 also vary from unadjusted values in predictable ways, but do not substantially alter the original interpretation that mothers born into "Privileged" families were not advantaged in the same way as fathers. Adjusted values for mother-daughter pairs in this "Privileged" sub-group result in a modest 0.55 cm reduction in mother-daughter height differences (3.88 to 3.33 cm). The greatest impact of adjustments was in the sub-group of mother-daughter pairs where maternal grandfathers were involved in business. In this group, mother-daughter height differences increased by 1.55 cm (3.51 vs. 5.06 cm). This is because this sub-group initially had the lowest level of parental height dimorphism (1.057 ± 0.010 SE). As shown in Fig. 1, this "Business" category is the only one where distributions of parental height dimorphism do not overlap in the two groups of families. This is curious, but may be the result of sampling error. The height dimorphism ratio in the sub-group of 16 families with sons whose maternal-grandfathers also were involved in business have parental height dimorphism ratios typical for the group as a whole (1.082 ± 0.015 SE). Since parental height dimorphism ratios logically

precede the categories of families based upon offspring sex, the relatively low ratio found in the "Business" families with daughters is probably the result of stochastic variation.

********** Fig. 3 **********

Overall, results reported here suggest that adjustment for differences in parental height dimorphism among families should at least be considered in studies examining sex-associated differences in growth among families. If same-sex parent-offspring height differences are as great as values reported in the present study, adjustments are unlikely to alter interpretations within the plausible range of variation in mean parent height dimorphism. If, however, a study has only somewhat larger number of participating father-son pairs ($N \approx 100$), smaller unadjusted mean differences in father-son heights across sub-groups ($\Delta \approx 2.5$ cm) would be statistically significant and might well be interpreted as biological meaningful. Because sample size increases do not alter the impact of adjustments for variation in parental height dimorphism, adjustment for height dimorphism differences like those reported here would result in non-statistically significant trend at a routine alpha level ($p \leq 0.05$). It may be reasonably argued that increasing numbers of participants would tend to reduce sub-group mean differences in parental height dimorphism if these differences are the result of random sampling error, but they may not be. Even if random, adjustment would still be worthwhile to permit direct comparisons of differences among sub-groups in this and other studies.

ACKNOWLEDGMENTS

I thank all of the participating Taiwanese families for their generosity of time and spirit. I also want to gratefully acknowledge Liao Shu-Fong, Zhao Zhu Lu, and Chao Chu-Kuen whose help in Taipei was crucial to success. I thank, too, Dr. Littleton, Dr. Guatelli-Steinberg, Dr. Battles, Caitlin Smith, Gina McFarlane, and Allison Wade, along with comments and criticisms from the

Associate Editor and two anonymous reviewers, for their help. This research was partially supported by UARC grants 3601710 / 9211 & 3602481 / 9211.

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TABLES (3)

Table 1. Anticipated bias of parent height dimorphism variation on unadjusted[a] same-sex parent-offspring height differences (parent height subtracted from offspring height), other circumstances being equivalent

Within a given human population:

1) If father to mother height ratio greater than average, then fathers tend to be tall relative to their spouses

Bias	**Assumed Reason**
Father-Son Δ reduced	To the extent that relative shortness of mothers is genetically influenced, this will be transmitted to sons so secular increases in sons' heights relative to those of their fathers will tend to be reduced, other circumstances being equivalent.
Mother-Daughter Δ increased	To the extent that relative tallness of fathers is genetically influenced, it will be transmitted to daughters so secular increases in daughters' heights relative to those of their mothers will tend to be increased, other circumstances being equivalent.

2) If father to mother height ratio less than average, then mothers tend to be tall relative to their spouses

Bias	**Assumed Reason**
Father-Son Δ increased	To the extent that relative tallness of mothers is genetic, this will be transmitted to sons so secular increases in sons' heights relative to those of their fathers will tend to be increased, other circumstances being equivalent.
Mother-Daughter Δ reduced	To the extent that relative shortness of fathers is genetically influenced, this will be transmitted to daughters so secular increases in daughters' heights relative to those of their mothers will tend to be reduced, other circumstances being equivalent.

[a] No measure of height dimorphism is included in estimation of mean height differences. If a measure, like father/mother height ratio is included in the model, identified biases on estimates of central tendency are reduced if assumptions are met.

Table 2. Results of regression analysis examining the influence of parental height dimorphism ratio (father's height / mother's height)[a] and paternal grandfathers' occupational categories on height differences between fathers and sons (father's height subtracted from son's height)

Criterion Variable: Father-Son Height Δ N: 56 Multiple R: 0.741 Adjusted multiple R^2: 0.522

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Father-Mother Height Ratio	715.80	1	715.80	44.56	<0.0005
Paternal Grandfather's Occupation	159.86	2	79.93	4.98	0.011
Error	835.29	52	16.06		

Durbin-Watson D Statistic: 1.83

First Order Autocorrelation: 0.07

[a] In a regression model that only includes the predictor Father-Mother Height Ratio, results are also highly statistically significant (Adj. $R^2 = 0.452$, $\beta = -76.88 \pm 12.76$, $t = -6.81$, $P < 0.0005$).

Table 3. Results of regression analysis examining the influence of parental height dimorphism ratio (father's height / mother's height)[a] and maternal grandfathers' occupational categories on height differences between mothers and daughters (mother's height subtracted from daughter's height)

Criterion Variable: Mother-Daughter Height Δ N: 51 Multiple R: 0.605 Adjusted multiple R^2: 0.325

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Father-Mother Height Ratio	725.71	1	725.71	26.16	<0.0005
Maternal Grandfather's Occupation	25.67	2	12.84	0.46	0.632
Error	1303.88	47	27.74		

Durbin-Watson D Statistic: 1.95

First Order Autocorrelation: 0.02

[a] In a regression model that only includes the predictor Father-Mother Height Ratio, results are also highly statistically significant (Adj. $R^2 = 0.340$, $\beta = 77.14 \pm 14.92$, $t = 5.17$, $P < 0.0005$).

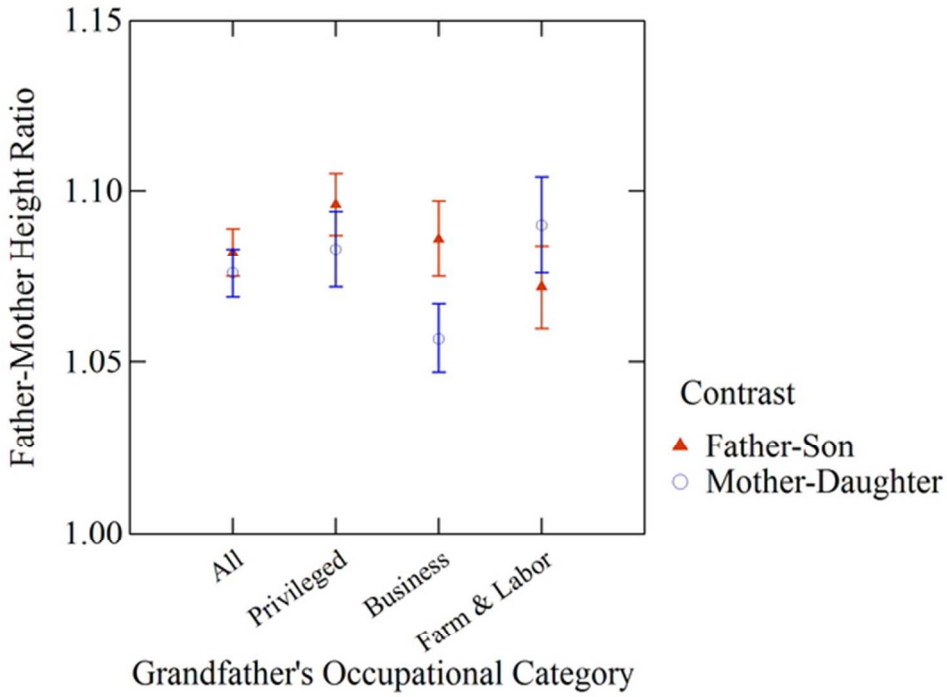
FIGURE LEGEND

FIGURES (3)

Fig. 1. Mean father/mother height ratio ± SE across paternal or maternal grandfathers' occupational categories for father-son or mother-daughter contrasts, respectively (father-son: All = 1.082 ± 0.007; Privileged = 1.096 ± 0.009; Business = 1.086 ± 0.011; Farming & Labor = 1.072 ± 0.012; mother-daughter: All = 1.076 ± 0.007; Privileged = 1.083 ± 0.011; Business = 1.057 ± 0.010; Farming & Labor = 1.090 ± 0.014).

Fig. 2. Mean father-son height differences ± SE (cm) by paternal grandfather's occupational category adjusted and unadjusted for parental height dimorphism (Privileged, Adjusted = 0.060 ± 1.22, Privileged, Unadjusted = -0.36 ± 1.63; Business, Adjusted = 4.06 ± 0.86, Business, Unadjusted = 3.82 ± 1.15; Farming & Labor, Adjusted = 5.28 ± 0.84, Farming & Labor, Unadjusted = 5.98 ± 1.13). Unadjusted values are from the original study (Floyd, 2016).

Fig. 3. Mean mother-daughter height differences ± SE (cm) by maternal grandfather's occupational category adjusted and unadjusted for parental height dimorphism (Privileged, Adjusted = 3.33 ± 1.21, Privileged, Unadjusted = 3.88 ± 1.49; Business, Adjusted = 5.06 ± 1.31, Business, Unadjusted = 3.51 ± 1.58; Farming & Labor, Adjusted = 4.15 ± 1.38, Farming & Labor, Unadjusted = 5.21 ± 1.68). Unadjusted values are from the original study (Floyd, 2016).



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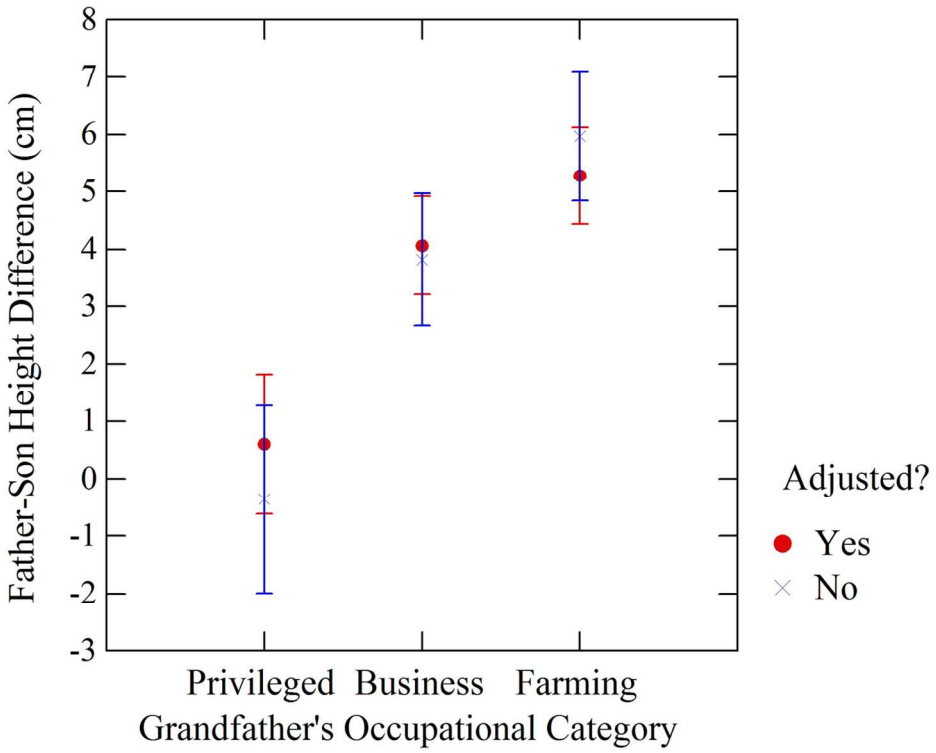

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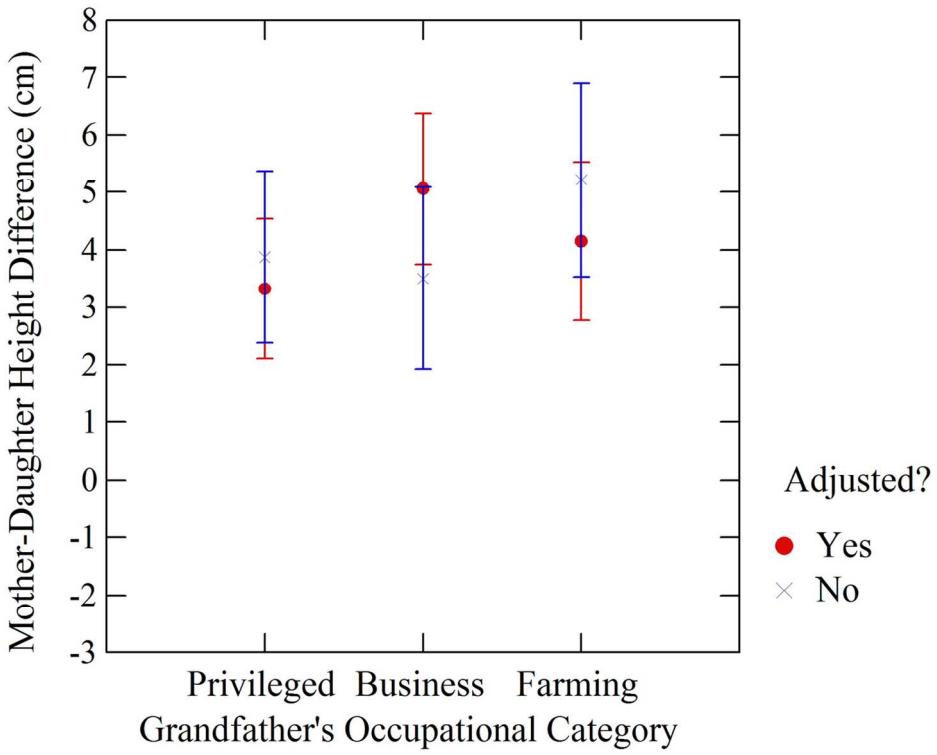

Fig. 3. Mean mother-daughter height differences ± SE (cm) by maternal grandfather's occupational category adjusted and unadjusted for parental height dimorphism (Privileged, Adjusted = 3.33 ± 1.21, Privileged, Unadjusted = 3.88 ± 1.49; Business, Adjusted = 5.06 ± 1.31, Business, Unadjusted = 3.51 ± 1.58; Farming & Labor, Adjusted = 4.15 ± 1.38, Farming & Labor, Unadjusted = 5.21 ± 1.68). Unadjusted values are from the original study (Floyd, 2016).

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