Gender Differences of Final Height Contributed by Parents' Height Among Healthy Individuals

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Key Words:corrected midparental; height; final parental height; gender difference; growth evaluation; target height

Background: Estimation of children's final height is of great interest for pediatric endocrinologists in diagnosing and evaluating the treatment of short stature. The current study was performed to characterize the feature of offsprings' final heights by their parents' heights by gender in Taiwan.
Methods: Healthy participants aged 25e35 years who underwent health examinations were recruited for body height measurements with standard processes regulated by a protocol and were enquired about their parental peak adult heights in 2003e2004. Differential contributions from each parent to the tallest/shortest child's height in the family were then assessed with simple linear regressions with scatter plots by gender. Meanwhile, statistical comparisons with the corrected midparental height method and final height for parental height model were performed.
Results: A total of 1113 male and 1036 female participants were enrolled. The fathers' height contributed the most to the tallest son's height in the family (adjusted R2Z0.20), and mother's height contributed the most to the shortest daughter's height in the family (adjusted R2Z0.18). Specifically, the final height for parental height line worked better for the contribution of midparental height to the tallest son's height in prediction.
Conclusions: For clinical practice, our results provided a reasonable estimation of final heights among local Taiwanese population and are also applicable for the evaluation of growth hormone replacement therapies for patients with short stature of non-growth-hormone defect.

1. Introduction

The final body height for adults is a polygenic trait influenced by numerous determinants, including nutrition; tempo of maturation; and genetic and environmental factors during fetal life, childhood, and adolescence.1e5 Estimation of a child's final height is of major significance for pediatric endocrinologists in diagnosing, evaluating the need for therapeutic intervention, and responding to parents' counseling.6 Stature of children is noticeably influenced by parental height,3,7,8 and meanwhile, the genetic basis of adult height is fairly perceptible in monozygotic twins who grow up apart.3 Genetic potential height or target height is usually determined as a function of parental height.9e12 Corrected midparental height (CMH) method computes the target height by adding or subtracting 6.5 cm to the mean of the parental heights for boys or girls, respectively,9 which has been commonly used by clinicians in the evaluation of growth-promoting therapies on growth hormone (GH)-deficient13 and non-GH-deficient children with short stature.14e16 However, midparental height might contribute more during earlier stage in an offspring's life11 and be limited for assessing short children of parents with extreme height.17 Another approach proposed for estimating target height is known as the final height for parental height (FPH) model.10 The FPH model is preferred for target-height estimation among Swedish children, as the CMH method leads to an underestimating bias of about 6 cm for children with short parents.9 One study compared the validities of CMH and FPH methods for estimating target height in Hong Kong Chinese
children.12 On average, this population was shorter than the Swedes by more than 10 cm. Their secular increase in height over the two generations, however, was 4.2e4.8 cm,
which was much greater than that of the Swedes (0.7e1.0 cm). Taiwanese people have experienced a dramatic socioeconomic transformation in the past 5 decades. Thus, the association between parental height and children's final height may also have changed.18 The aim of this study was to suggest a new approach to characterize the feature of tallest/shortest boys' and girls' final heights, predicted by the height of their parents in a large sample of healthy Taiwanese who were born in the 1970s. Our results may provide further insight into the basis for enhancing accuracy in the estimation of target height by
each gender and further evidence of differential contribution from male/female parents for the achieved final height for boys and girls.

2.Methods

2.1.StudysettingDuringtheperiodfromJuly1,2003,toJune30,2004,theinvestigatorsrecrui

ted1229familieswithhealthyoffspringsagedbetween25yearsand35yearsforhealthexaminationsatamedicalcenterincetralTaiwan.Age,sex,height,andexaminedmedicalandfamilyhistoriesweрerecordedatclinicalvisits.Familieswitheitherparentsoroffspringshavinghypopituitarism,hypothy-roidism,chromosomalabnormality,historyofpoliomy-elitis,antenatalbetamethasoneexposure,ormalnutritionwereexcludedfromouranalyses.

2.2.Datacollection

Dataaboutoffsprings'bodyheightswerecollectedbyaquestionnaireafterthestandardmeasurementsoftheirparents'heightswitacalibratedHarpendenstadiometer(theheightbaronastandardhospitalscale)byawell-trainedstaffinhealthexaminations.Parentswererequestedtoreporttheiradultpeakheight,numberofoffspringsineachgender,andheightoftheirtallest/shortestsonsanddaughters.Thus,eachfamilyprovidedjustonesetofheightinformationtoavoidtheviolationofindependentobservationassumptioninstatistics.Self-reportedpeakadultheightforparentswasobtained,becausemostoftheseindividualswereintheir50sand60s.Theyhadexperiencedaging-relateddecreasesinheight.

Midparentalheightwasdefinedastheaverageoffather'sandmother'sreportedheights.Thestudywasapprovedbythehospitalethicscommittee,andinformedconsentwasobtainedfromallparticipants.192.3.StatisticalanalysesTwoanalyticalschemesofattemptsweretakenforthisstudy.Wetriedtodistinguishthedifferentialcontributionsfromeachparenttothetallest/shortestchild'sheightinthefamilybygender.Iftherewasonlyonesonordaughterinafamily,theonlysonordaughterwastakenastheshortestandalsothetallestoneinthefamilyforanalyses.

Simplelinearregressionswereusedfortheestimationoftargetheightsoftheoffspringsbyparentalheights.Theexplainablevariationofindependentvariables,parentalheights,withthedependentvariables,children'sfinalheights,wasexpressedbyadjustedR2,theR2adjustedforthenumberofparametersinvolvedinthemodel.Scatterplotswithlinearregressionlineswereusedtodepictthedistributionofchildren'sfinalheightsoverparentalheights.Bvalues(slopes),intercepts,andtheir95% confidenceintervalswereestimatedfortheeffectofparentalheightonchildren'sfinalheight.

Meanwhile,forthepurposeofdetectingthedifferencesbetweenmodelsofparentalheightspredictingtallest/shortestchildreninthefamily,statisticaltestsforcomparinginterceptsandslopesbetweenregressionswereperformed.Then,thecomparisonsofthescenariosoftallest/shortestson/daughterpredictedbymidparentalheightwiththeCMHmethod20andtheFPHmodel10wereperformed.CMHmethodpredictsthetargetheightbyadding6.5cmtothemidparentalheightinboysorsubtracting6.5cmfromthemidparentalheightingirls.20TheFPHmodelforestimatingtargetheight(Y)asasimplelinearfunctionofmidparentalheight(X)incentimeters(boys:YZ45.99t0.78X;girls:YZ37.85t0.75X)wasbasedonaSwedishseries.10SPSS13.0forWindows(SPSSInc.,Chicago,IL,USA)andStata/SEversion8.0(StataCorpLP,CollegeStationTX,USA)wereusedtoperformthestatisticalanalyses,andthesignifi-cancelevel(avalue)wassetas0.05.184P.-H.Suetal

3.Results

3.1.GeneralfeaturesofthestudyparticipantsAtotalof1113maleparticipants,1036femaleparticipants,andtheirparentswereenrolledfortheanalyses.Themeanandstandarddeviationfortallest/shortestsons,daughters,theirfathers,andmotherswere173.19(5.20)cm/168.30(5.77)cm,161.65(4.87)cm/156.99(4.70)cm,168.34(5.59)
cm,and157.04(4.85)cm,separately.Amongthesefamilies,theaveragenumbers(standarddeviation)ofsonsanddaughterswere2.42(1.25)and2.55(1.39),respectively,witharangeof1e9sonsordaughters.

3.2.Predictingoffspring'sfinalheightbyparent'sheightThestatisticsforpredictingtallest/shortestchildinthefamilybyparentalheightswithlinearregressionsarepresentedinTable1.Allthepvaluesfortestinginterceptsandslopesdifferingfromzerowerelessthan0.01.Father'sheightcontributedthemosttotallestson'sheightinthefamily(adjustedR2Z0.20)andtheleasttotheshortestdaughter'sheightinthefamily(adjustedR2Z0.11).
Nonetheless,mother'sheightcontributedthemosttotheshortestdaughter'sheightinthefamily(adjustedR2Z0.18)andtheleasttotheshortestson'sheightinthefamily(adjustedR2Z0.13)
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3.3.Figuresforfittedregressionlinesandcomparisonwithexistingheightestimationmethods
Figures1AeHillustratetheeightscenariosforthedistibutionofeachobservationandfittedlinearregressionlines.Forbettervisualimpression,verticalandhorizontalscalesforallthefigureswereunified(from150cmto200cm).Intermsofthecomparisonsofinterceptsandslopesamongmodelsofparentalheightspredictingtallest/shortestchildreninthefamily,alltheinterceptsweresignificantlydifferentfromeachother(allp<0.01),butonlytheslopedifferencesbetweenfathers'heightpre-dictingtallestandshortestsons(i.e.,0.42vs.0.37)revealedborderlinestatisticalsignificance(pZ0.07,
detailsnotshown).Figures2AeDpresentthepredictingscenariosofmidparentalheightstotallest/shortestsonsanddaughterswithCMHandFPHregressionlinesasbenchmark.WhenweusedtheTaiwanesemidparentalheighttopredictthetallestson'sheight(adjustedR2Z0.32),theregressionlineandFPHlinealmostover-lappedfrom160cmto180cmofmidparentalheight(Figure2A).InFigure2,thepredictionlineofthecurrentstudyisparalleltotheFPHlineconstantlyalltheway.Inaddition,CMHpredictionwasclosertothepresentstudyparticipantsatlessermidparentalheights,butitshiftedtowardtheFPHlineatgreatermidparentalheights.
Figure2Cillustratesthepredictionofthecontributionofmidparentalheightstothetallestdaughters'heightsinthestudyfamilies,comparingtheCMHandFPHlines.Theydifferthemostatlowmidparentalheight,andthentheyreachacommonpredictionpointaroundthemidparentalheightof178cm.Finally,thepatternshowninFigure2Dwasverysimilartothatin Figure2B.
ThedistancebetweenthepresentstudylineandFPHdidnotaltermuchfromthemidparentalheightof150e180cm.ItsCMHlinewasclosertothepresentstudylineatlessermidparentalheight,butshiftedtowardFPHlineatgreatermidparentalheight.Insummary,theFPHlineperfor

medabetterpredictionofthecontributionofmidparentalheightstotheheightsofthetallestsonsinthefamiliesofthepresentsudy,andtheachievementsvariedinotherscenarios.Toacertainextent,specificpatternsintheobservationsamongtheTaiwanesepopulationforfinalheightpredictionwithrespecttothetallest/shortestsons/daughterswerecharacterizedbyourstudyresults.

4.DiscussionWithahugenumberofhealthyparticipants,wefoundthatfather'sheightcontributedthemosttothetallestsons'heightinthefamilyandmother'sheightcontributedthemosttotheshortestdaghter'sheightinthefamily.

Furthermore,inthepresentstudy,wecomparedthelinearregressionlinesusingTaiwanesemidparentalheightstopredicttallest/shortestsons'anddaughters'heightswithCMHandFPHregressionlines.Specifically,theFPHlineperformedabetterpredictiononcontributionofmid-parentalheighttothetallestson'sheightinthefamilybutnotintheotherscenarios.Wefoundthatthegenerational

Table1Predictingthetallest/shortestsons'anddaughters'finalheightsbyparentalheightswithsimplelinearregressions*

VariablesSons'heightsincm(Y;nZ1113)		Daughters'heightsincm(Y;nZ1036)	
TallestsonShortestsonTallestdaughterShortestdaughterFather(X)AdjustedR2Z0.20AdjustedR2Z0.13AdjustedR2Z0.13AdjustedR2Z0.11Intercept(cm)(95%CI)102.40(94.12e110.68)105.26(95.67e114.86)109.58(101.25e117.91)109.72(101.59e117.84)			
Slope(95%CI)0.42(0.37e0.47)0.37(0.32e0.43)0.31(0.26e0.36)0.28(0.23e0.33)			
Mother(X)AdjustedR2Z0.14AdjustedR2Z0.13AdjustedR2Z0.15AdjustedR2Z0.18Intercept(cm)(95%CI)109.26(100.09e118.43)99.82(89.58e110.06)101.14(92.24e110.04)92.33(83.90e110.77)			
Slope(95%CI)0.41(0.35e0.47)0.44(0.37e0.50)0.39(0.33e0.44)0.41(0.36e0.47)			

*Allpvalueslessthan0.01fortestinginterceptsandslopesdifferingfromzero.

CIZconfidenceinterval.

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increasesinheightsofTaiwaneseparentsandtheiroffspringswerebetweenthoseofHongKongChineseandSwedishpeople,allborninsimilaryearsofthe1970s.TheCMHmethodunderestimatedthefinalheight,whereastheSwedishFPHmodelmayoverestimateit.18Thecontributionfromaparenttothetallest/shortestchildinthefamilyvaried.Nonetheless,theperformanceofFPHmodelfavoredthepredictionofmidparentalheighttothetallestsoninafamilyamongthisTaiwanesepopulation.

Themajoradvantageofthepresentstudywastherelativelylargernumberofparticipantsin Taiwan.Althoughfactorsaboutdietintake,physicalactivity,andpubertyage,whichalsocooperativelydeterminefinalheight,werenotavailable,theapproachofinnovativeattemptsbypredictingthefinalheightofthetallest/shortestboys/girlsprovidedinsightintothisissueinTaiwanesepopulation.

Inclinicalsettings,themajorapplicationoftarget-heightassessmentonendocrineconditions wouldbeinFigure1(A)Thecontributionoffather'sheighttothetallestsoninfamily(YZ102.40t0.42X;adjustedR2Z0.20;pvalueforslope<0.01;nZ1113).(B)Thecontributionoffather's heighttotheshortestsoninfamily(YZ105.26t0.37X;adjustedR2Z0.13;pvalueforslope<0.01;nZ1113).(C)Thecontributionofmother'sheighttothetallestsoninfamily(YZ109.26t0.41X;adjustedR2Z0.14;pvalueforslope<0.01;nZ1113).(D)Thecontributionofmother'sheighttotheshortestsoninfamily(YZ99.82t0.44X;adjustedR2Z0.13;pvalueforslope<0.01;nZ1113).(E)Thecontributionoffather'sheighttothetallestdaughterinfamily(YZ109.58t0.31X;adjustedR2Z0.13;pvalueforslope<0.01;nZ1036).(F)Thecontributionoffather'sheighttotheshortestdaughterinfamily(YZ109.72t0.28X;adjustedR2Z0.11;pvalueforslope<0.01;nZ1036).(G)Thecontributionofmother'sheighttothetallestdaughterinfamily(YZ101.14t0.39X;adjustedR2Z0.15;pvalueforslope<0.01;nZ1036).(H)Thecontributionofmother 'sheighttotheshortestdaughterinfamily(YZ92.33t0.41X;
adjustedR2Z0.18;pvalueforslope<0.01;nZ1036).

determiningshortstatureandprecociouspuberty.Fortheissueofshortstatureofnon-GH-defectpatients,ourstudyresultsprovideamorereasonablerangeoffinalheightsamonglocalpopulation,ratherthanusingthebiaseduniversalCMHestimations.Meanwhile,forthepatientswithGHdefect,ourresearchoutcomeisalsoessentialfortheevaluationofGHreplacementtherapyandfine-tuningonprescriptiondosage.Asforprecociouspuberty,becauseofearlyepiphysealplatedevelopmentresultinginitsprematureclosureandshortadultheight, gonadotropin-releasinghormoneanalogisusedfordelayingtheprogressandthenlettingpatientsapproachidealfinalheight.Thus,furtherunderstandingaboutthenormalrangeoffinalheightofTaiwanesepopulationfacilitatestheassessmentofgonadotropin-releasinghormonetreatmentsinclinics.Meanwhile,limitationsofthepresentresearchalsoexist.First,thisisaretrospec-tivestudy,notalongitudinalone.Second,parentalheightwasself-reportedinquestionnaires,whichmightresultininformationbias.Third,heightsamongsiblingswithinafamilyvary.Iftherewasonlyoneboy/girlinafamily,he/sheservedasthetallest/shortestboy/girlinthepredictionmodelatthesametime.Themorethekidsinafamily,thebetteristhepossibilitytofindparticipantswithextremeheights.Consequently,biggerfamiliesmightprovidemoreexceptionallytallorshortparticipantsinthefinalheightpredictionmodelassuggestedbythepresentresearc.Lastly,variablesofpotentialconfoundersaboutnutrition,menarcheageoffemaleoffspring,andexercisewerenotavailableinthelarge-scalestudyforanalyses, whichmightdecreasetheprecisionofpredictionofoffspring'sfinalheight. Astosuggestionsforfurtherstudiesinfuture,differen-tialeffectsofenvironmentalstressonadultheightbygenderareofmajorinterest.4Follow-upstudiesofpop-ulationsofdifferentracesmightbebeneficial,intermsofactivedatacollectionandfinalheightmeasurementsduringthestudyperiod.Furthermore,somemoredataon

Figure1(continued).

Figure2(A)Thecontributionofmidparentalheighttothetallestsoninfamily(YZ49.13t0.76X;adjustedR2Z0.32;pvalueforslope<0.01;nZ1113),comparingtheFPHandCMHregressionlines.(B)Thecontributionofmidparentalheighttotheshortestsoninfamily(YZ48.32t0.74X;adjustedR2Z0.24;pvalueforslope<0.01;nZ1113),comparingtheFPHandCMHregressionlines.(C)Thecontributionofmidparentalheighttothetallestdaughterinfamily(YZ60.43t0.62X;adjustedR2Z0.25;pvalueforslope<0.01;nZ1036),comparingtheFPHandCMHregressionlines.(D)Thecontributionofmidparentalheighttotheshortestdaughterinfamily(YZ57.69t0.61X;adjustedR2Z0.26;pvalueforslope<0.01;nZ1036),comparingtheFPHandCMHregressionlines.CMHZcorrectedmidparentalheight;FPHZfinalheightforparentalheight.environmentalfactorswouldbehelpfultostudyissuesregardinggeneeenvironmentinteractions.Twinstudiesoradaptationstudiescouldprovideadvancedinsightforsuchstudy.

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