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STUNTING INDUCED BY WASTING — WASTING INDUCED BY STUNTING: A CASE STUDY[¶]

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ABSTRACT

Background: Stunting and wasting are accepted, widely, as health-risk indicators of individuals at micro level, and that of population at macro level. These two conditions, when present together in a child, are the early-warning signals in the context of health-and-nutrition status. However, link between stunting and wasting has been rarely studied.
Case Presentation: Association between the two conditions was observed in 2 sisters (QJ and JJ), who were registered in SF Laboratory's growth-monitoring program. They were part of a family, consisting of father, mother, 3 daughters and a son. This family was monitored for a period of 4 years (2007-2011), through anthropometric measurements of all 4 siblings. Height- and mass-data analysis indicated that wasting, present for a longer period, in the elder sister (QJ) may be the cause of a marked drop in height, while the anthropometric-data analysis of the younger one, JJ, gave some evidence in favor of wasting being induced by stunting.
Mathematical Model: Mathematical-statistical model, given by Kamal, Firdous and Alam in 2004, was modified to study the cases presented. Concepts of growth (height) velocity and mass (weight) gain (loss) were abandoned and replaced by trajectories as well as height and mass percentiles. A jumping up (down) on these trajectories represented 'real-gain (-loss)'. A physical gain in height (mass) over a certain period, accompanied by a drop in percentile during the same period was interpreted as 'pseudo-gain'.
Conclusion: This family's data highlighted stunting, induced by wasting and wasting, induced by stunting. Besides investigating association between stunting and wasting, we, also, tried to find out the underlying mechanisms and discover the agents causing the two conditions. Longitudinal studies should focus on physiological and psychological bases of the potential relations of childhood stunting and wasting, starting from conception and following children till old age, in particular, looking for prevalence of stunting (with associated wasting) in a community and vice versa.

Keywords: Children, energy channelization, optimal-mass management, stunting, wasting, obesity, over-nutrition, under-nutrition, lifestyle adjustment, diet plan, real-gain, pseudo-gain

LIST OF ABBREVIATIONS

BMI: Body-mass index
NGDS: **N**ational **G**rowth and **D**evelopmental **S**tandards for the Pakistani Children
SF: Syed Firdous
SGPP: **S**ibling **G**rowth **P**ilot **P**roject — a subproject of the NGDS Pilot Project

BACKGROUND

Stunting and wasting are 2 major problems facing the child population in developing countries and is a matter of most field studies. A recent study by Murage *et al.* (2010) investigated prevalence of stunting, overweight and obesity, and metabolic disease risk in rural South African children. However, links between stunting and wasting have been studied by only a few (Ferreira *et al.*, 2008; Maiti *et al.*, 2012; Martorell and Young, 2012; Richard *et al.*, 2012; Stevens *et al.*, 2012).

For children, who are stunted and wasted, under-nutrition and/or chronic diseases might be the main concerns, requiring complete head-to-toe examination. Over-nutrition might cause tallness plus obesity, which amplifies tissue-synthesis rate and storage in body. The remaining two possibilities, stunting with obesity and tallness with wasting, might arise due to energy-channelization problem in body, *i.e.*, a large amount of micronutrients, all flowing through one channel of absorption. Stunting with obesity may be caused by storage of most micronutrients; whereas tallness with wasting, could result from micronutrients, mostly, involved in tissue synthesis. According to Chianese (2005), "obesity in a short child increases suspicion of endocrine or genetic disorders" A proper study of this problem should take into account regional variations in physiques. Asians, for example, have low-energy expenditure, which may be attributed to their body composition (Adriaens and Westerterp, 2008).

[¶]The italic superscripts [a], [b], [c], …, appearing in the text, represent endnotes listed before references.

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Fig.1. Nutrition and energy-channelization**:** their effects on statuses of height and mass — *stunting* and *wasting*, when exist together in a child, may suggest under-nutrition, while if *stunting* occurs with *obesity*, there might be some hormonal problems, *e. g.*, growth-hormone deficiency, which is hindering growth, and most of the nutrients taken in might be utilized in weight gain. *Obesity* occurring with *tallness* might be a case of simple *obesity* due to over-eating. *Tallness* along with *wasting* suggests that most of the dietary nutrients are exhausted in the process of height gain (http://www.ngds-ku.org/Papers/J32/Fig_1.htm)

In this paper, we present cases of stunting, induced by wasting, and wasting, induced by stunting, in a family of 4 siblings. Their father contacted the NGDS Team regarding possible short stature of his number 2 and 3 daughters, after hearing a live interview of first author (SAK) broadcast by a local radio station on December 19, 2006. Although the cases, described in this paper, are not cogent evidence ascertaining direct causal relationship between stunting and wasting, they do indicate that there may exist some indirect relationship between the two. Under-nutrition seems to be a key factor causing both problems (Flores-Mira *et al.*, 2005; Mamiro *et al.*, 2005; Binagwaho *et al.*, 2011). There are indications that diarrhea during weaning period is positively correlated with childhood stunting (Bhutta, 2002; Checkley *et al.*, 2008), whereas meat consumption reduced stunting in toddlers (Krebs *et al.*, 2011). Effects of under-nutrition, over-nutrition and energy-channelization[a] on co-existence of stunting (tallness) with wasting (obesity) are summarized in Figure 1.

CASE PRESENTATION

Data Collection

The NGDS Pilot Project[b] was initiated in 1998 under of directives of Governor Sindh/Chancellor, University of Karachi. It was designed after considering North American and European, ethical and human-right standards (Kamal *et al*. 2004). SF-Growth-and-Imaging Laboratory provides services to the community in the field of family-health care — families with children, having growth-related problems, register with our growth-monitoring program, officially recognized as SGPP (Sibling Growth Pilot Project). SGPP is a subproject of the NGDS Pilot Project. Families can benefit from this program by filling out and signing *the SGPP Participation Form*[c]. Some children have presented with unusually short stature, at the same time dropping well below their optimal mass (weight)[d], with the passage of time. On the other hand, a few children were severely wasted, when they were first checked, and with the passage of time they, also, became stunted. **Additional File 1** consists of detailed project protocols[e].

Heights and masses were measured to accuracies of 0.1 *cm* and 0.1 *kg*, respectively, with the children undressed to short underpants, all clothing above the waist removed (Kamal, 2006). The equipments were calibrated at the beginning of every session. Mid-upper-arm circumferences (MUAC) were measured to accuracies of 0.1 *cm*, on both right and left arms. Father's (Mother's) mass was *gross mass*, converted to *estimated-net mass* (mass with no clothing on) by applying a suitable clothing correction. Children wore only briefs or panties and, hence, their masses were used in calculations without any clothing correction. The children were measured with due regard to privacy, confidentiality[f] and comfort of the participants (Kamal, 2006). Parents were given the opportunity to discuss their children's growth-and-obesity profiles with the Project Director.

A mathematical-statistical model was developed to study the case of J. Family. Detailed model is described in **Additional File 1**. Here, we give the salient features. According to Kamal *et al.* (2004), height and mass graphs were assumed to be linear, for measurements performed in a short span of time — a good approximation for most regions. Heights at different age-grids were computed using linear interpolation. Child's target height (in *cm*) was computed by adding (subtracting) 6.5 *cm* to (from) average height (*cm*) of biological parents (Tanner *et al.*, 1970). Pakistani growth charts were not available at the time of examinations. The best estimate was target height, which was extrapolated backwards to compute current-age-mid-parental height. A positive (negative) difference of current-age-mid-parental and interpolated-actual heights, at the same age indicated whether the child was *stunted* (*tall*). Body-mass index (BMI) was computed by taking ratio of mass (in *kg*) to square of height (in *meter*). However, the definition and perception of obese (wasted), based on BMI scale, is not applicable for children, in which case BMI tables must be used (Kamal *et al.*, 2013*c*). Kamal and Jamil (2012) introduced *estimated-adult BMI*, ratio of estimated-adult mass to square of estimated-adult height. This parameter could, roughly, predict obesity status in adulthood without using children's BMI tables. For a better estimate, optimal mass (Kamal *et al.*, 2011*b*; 2013*c*) was determined and compared with actual mass. A positive (negative) difference of actual and optimal masses indicated that the child was *obese* (*wasted*).

This model has been slightly modified for the purpose of computing growth-and-obesity profiles of children over a period of time. Growth (Height) velocity and mass (weight) gain (loss) concepts were abandoned. Height and mass percentiles did the job, just like the altitudes at which aircrafts are flying. At times, we noticed a numerical gain of height or mass over a certain period of time. However, if the respective percentile dropped during the same period, it was not a *real-gain*, but a *pseudo-gain*. A jumping up (down) on percentile trajectories represented a real-gain (-loss). For height or mass extreme values (below 3rd or above 97th percentile), logistic regression/linear interpolation was used to compute numerical values. KJK (Kamal-Jamil-Khan) model (Kamal *et al.*, 2011*b*), employing *growth tables* (Kamal and Jamil, 2012) obtained from *growth charts*, released by Centers for Disease Control and Prevention[g], was used to compute single-checkup-growth profile. Although, these growth charts are meant for assessment of US population, they are being used in other countries, too.

Here, we illustrate the phenomena of 'stunting induced by wasting' and 'wasting induced by stunting' through an example, in which this kind of association between these two conditions was observed. The family, consisting of biological parents, 3 girls (ZJ, QJ and JJ) and a boy (TJ) reported for first checkup in May 2007, with follow-ups in September/October 2007, June 2008 and February 2009 (Figure 2). A final checkup was conducted in March 2011 for evaluation of efficiency and effectiveness of intervention strategies. History provided by mother indicated obesity problem in ZJ, severe wasting and marked behavior change in QJ, severe stunting and hyperactivity in JJ, hyperactivity and stubbornness in TJ. During the checkups parents showed enthusiasm in learning about medical equipment and complied with all the instructions given to them.

QJ failed to gain height and mass (weight). Her mass percentile dropped, constantly, during successive checkups, falling below 3rd percentile after 2nd checkup. QJ's examination showed white spots on nails and back asymmetry on forward bending and visual inspection. JJ, also, failed to pick up height and mass (both below 3rd percentile at the age of 8.0 *years*). Examination revealed unkempt, hyperactive, talkative child with yellow teeth and MUAC (mid-upper-arm circumferences) different on right (16.1 *cm*) and left (16.5 *cm*) arms.

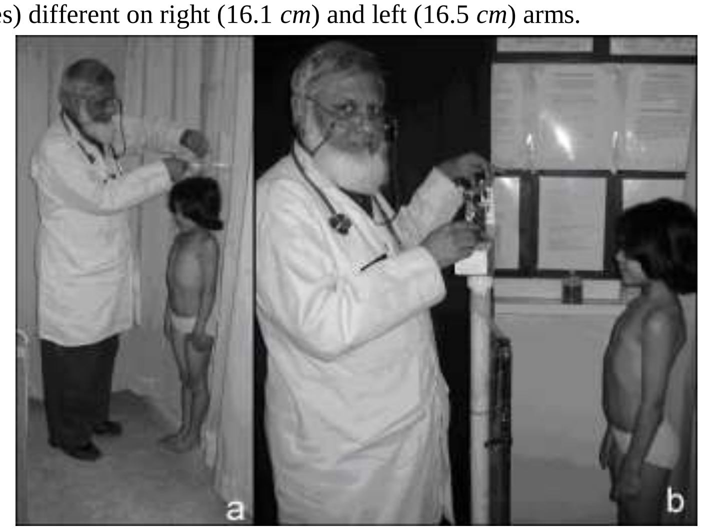

Fig. 2. Measurements of *(a)* height and *(b)* mass of JJ — photographs taken on February 08, 2009;
age: 8 years 1 month 14 days (http://www.ngds-ku.org/Papers/J32/Fig_2.htm)

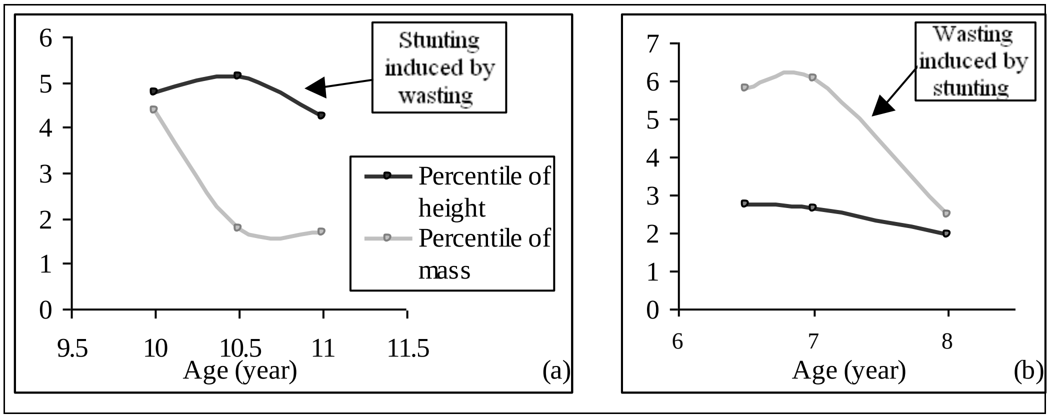

Fig. 3. Height and mass percentiles of two sisters, *(a)* QJ and *(b)* JJ show that QJ was a wasted child and remained wasted throughout the follow-ups. But initially (1st checkup) the difference between her height and mass percentiles was not significant, later (2nd check up) a notable drop in mass percentile was noted, with a slight increase in height percentile. 3rd checkup of this child showed a marked drop in percentile of height, which we interpret as being caused due to persistence of wasting. On the other hand, JJ was obese and stunted child. She remained stunted throughout her checkups but her mass percentile dropped significantly after 2nd checkup. We infer from this that drop in percentile of mass is due to being stunted (http://www.ngds-ku.org//Papers/J32/Fig_3.htm)

RESULTS

Both parents have short height (mid-parental height lies at, approximately, 9th percentile — 8.81, to be exact, for girls and 9.43 for boys) and are obese — father 38.97% (first checkup) and 35.97% (final checkup); mother 15.50% (first checkup) 15.91% (final checkup). According to Figure 3, QJ's height percentile shows a slight increase, reaches a maximum and then takes a downward turn, as indicated by percentile values, 4.77, 5.10 and 3.84 at 10.0 *years* (between 1st and 2nd checkup), 10.5 *years* (between 2nd and 3rd checkup) and 11.0 *years* (between 3rd and 4th checkup), respectively; whereas mass percentile shows a constant decrease, as shown by percentile values, 4.37, 1.78, 1.66 at 10.0 *years*, 10.5 *years* and 11.0 *years*, respectively. Non-integral values of percentiles are obtained by linear interpolation. These may be termed as *interpolated percentiles*. As illustrated in Figure 4, the elder sister, QJ remained stunted (1.90% between 1st and 2nd checkup, 1.41% between 2nd and 3rd checkup, 2.27% between 3rd and 4th checkup) as well as wasted (0.82% between 1st and 2nd checkup, 5.53% between 2nd and 3rd checkup, 4.76% between 3rd and 4th checkup) throughout this period.

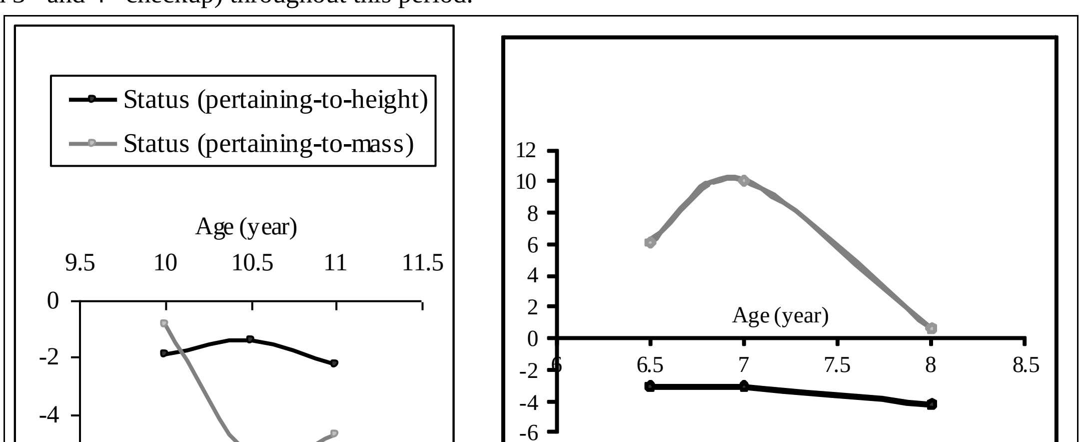

Fig. 4. Statuses (pertaining-to-height and -mass) of *(a)* QJ and *(b)* JJ — besides demonstrating stunting induced by wasting and wasting induced by stunting, statuses (pertaining-to-height and -mass) of the two sisters, QJ and JJ, bring out another very interesting phenomenon. Status (pertaining-to-mass) of QJ is a mirror reflection of status of JJ. There is a hypothesis that JJ would, probably, follow the curve of QJ, because she belongs to the same family-genetic code. Discovery of such hidden curves should be the focus of future mixed-longitudinal-sibling studies. Status (pertaining-to-height) is, almost, flat, suggesting a uniform gain of height. The apparent Variations may be due to different rates of growth in summer and winter as well as measurement errors (http://www.ngds-ku.org/Papers/J32/Fig_4.htm)

On the other hand, JJ's height percentile, according to Figure 3, shows a constant decrease, as indicated by percentile values, interpolated for 6.5, 7.0, 8.0 *years*, which are 2.74, 2.61 and 1.97, respectively; whereas mass percentile reaches a maximum and then drops down, as shown by percentile values, 5.80, 6.04, 2.48 at 6.5 *years*, 7.0 *years* and 8.0 *years*, respectively. JJ remained stunted (3.08% between 1st and 2nd checkup, 3.10% between 2nd and 3rd checkup, 4.16% between 3rd and 4th checkup) as well as obese (6.14% between 1st and 2nd checkup, 10.06% between 2nd and 3rd checkup, 0.65% between 3rd and 4th checkup) throughout this period, as illustrated in Figure 4 (next page).

We, briefly, describe growth-and-obesity profiles of other 2 siblings. ZJ, the eldest sister, constantly, climbed up on the height trajectory. She was, however, dropping down on mass trajectory, thus reducing her obesity level. The youngest of the family, TJ dropped his height percentile, slightly, from 2nd to 3rd checkup and, then picked up. He was, however, diving down on mass trajectory, thus taking him from optimal-mass management to becoming wasted. **Additional File 2** has detailed case documentation[h].

CONCLUSION AND FUTURE DIRECTIONS

This family's data brought out a very interesting phenomenon, stunting, induced by wasting (case of QJ) and wasting, induced by stunting (case of JJ). The authors suggest a need to study physiological and psychological (Walker *et al.*, 2007) bases of the potential relations and mechanisms of childhood stunting and wasting through comprehensive longitudinal studies, following stunted and wasted children, beginning right from infantile period (Lawlor *et al.*, 2007) or even before (Han *et al.*, 2011) and continuing through childhood, puberty, adolescence (Walker *et al.*, 2007), adulthood and old age. A good starting point could be the study of prevalence of stunting (Onis *et al.*, 2003) in a community, and finding out wasting present in stunted children. A similar study could be focused on determining prevalence of wasting, and then discovering stunting in wasted children.

This family presented another noticeable phenomenon, which has been hinted by other researchers, also (Caballero, 2005) — underweight and obesity going hand-in-hand in the same family. While ZJ had marked obesity as the major problem, QJ showed severe wasting. JJ was referred to our laboratory for failure to gain height — stunting was confirmed upon examination.

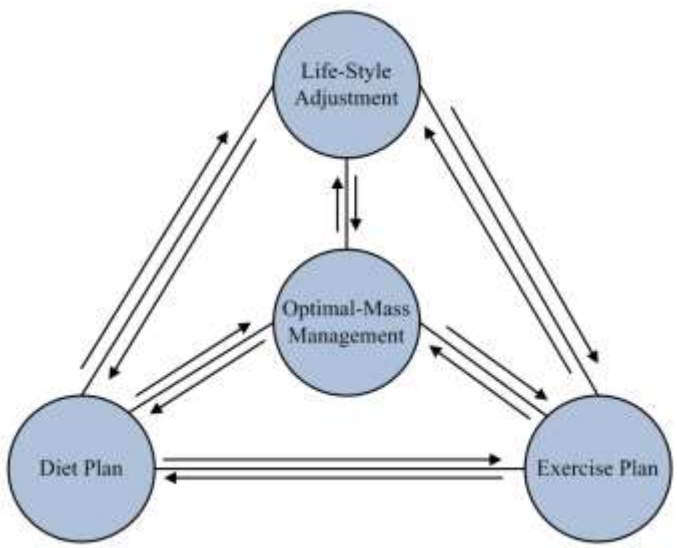

Fig. 5. Three factors contributing to optimal-mass management — a delicate balance of life-style adjustment, diet plan and exercise plan would help in optimal-mass management (http://www.ngds-ku.org/Papers/J32/Fig_5.htm)

The method presented in this work is robust and could be used to predict heights and masses 6-month ahead and, therefore, could form the basis of a comprehensive plan for target-height achievement (target height is defined by Tanner and is based on mid-parental height) (Kamal *et. al.*, 2013*b*) as well as optimal-mass management (Kamal *et. al.*, 2013*c*) in children and adolescents by reducing under- (Subramanyam *et al.*, 2011) and over-nutrition. *Optimal-mass management* is the optimal solution among three factors (Figure 5) — diet plan, exercise plan and, more importantly, life-style adjustment (Kamal *et. al.*, 2011*a*). Life-style with a positive mindset (freedom from depression), an effective social interaction (family, friends, workmates), a balanced daily routine (appropriate screen time, walking, light exercise), may contribute towards achieving this goal (Kamal *et. al.*, 2013*c*). It is to be noted that all diet-based interventions for height and mass management are ineffective if the child is suffering from vitamin-D deficiency (Kamal *et. al.*, 2013*a*).

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ENDNOTES

[a]Credits for the concepts of energy channelization, over- and under-nutrition as well as drawing of Figure 1 go to SSJ. The drop in percentile of height and physical gain of weight, as a child approaches puberty, is an illustration of energy-channelization problem.

[b]The NGDS (National Growth and Developmental Standards for the Pakistani Children) Pilot Project (http://ngds.uok.edu.pk) is a community-based project dealing with child growth and optimal-weight management of families since 1998, based on Opt-in Policy. The *Informed Consent Form* is uploaded at:

http://www.ngds-ku.org/ngds_folder/Protocols/NGDS_form.pdf

[c]*The SGPP Participation Form* (http://www.ngds-ku.org/SGPP/SGPP_form.pdf) explained SGPP protocols (http://www.ngds-ku.org/ngds_URL/subprojects.htm#SGPP) and provided links to reading material and procedure-photographs.

[d]The concept of *optimal mass (weight)* was introduced by the first author in 2011 as the mass (weight), whose percentile matches with the percentile of current height (Kamal *et al.*, 2011*b*).

[e]**Additional File 1** (http://www.ngds-ku.org/Papers/J32/Additional_File_1.pdf) consists of detailed project protocols, laboratory techniques and mathematical-statistical model, which was developed for data analysis.

[f]Family labels and children's initials presented in this manuscript and supplementary documents do not correspond to first letters in actual names (as per confidentiality standards established by our group). Same is true about case numbers appearing in the main and the additional documents.

[g]The calculations presented in this work are based on growth charts released by Centers for Disease Control and Prevention (http://www.cdc.gov), Atlanta, GA, USA.

[h]**Additional File 2** (http://www.ngds-ku.org/Papers/J32/Additional_File_2.pdf) consists of detailed case documentation (additional figures, formulae, description of the model used, and tables listing growth-and obesity profiles of all family members, in easy-to-understand language).

REFERENCES

Adriaens, M. P. E. W. and K. R. Westerterp (2008). Low resting energy expenditure in Asians can be attributed to body composition. *Obesity*, 16: 2212-2216.

Bhutta, Z. A. (2002). Optimizing maternal and fetal nutrition: The best investment for the future. *The Aga Khan University National Health Sciences Research Symposium: Early Childhood Care and Development*, Kara-chi (Pakistan), p. 5.

Binagwaho, A., M. Agbonyitor, A. Rukundo, N. N. Ratnayake, F. Ngabo, J. Kayumba, B. Dowdle, E. Chopyak and M. C. S. Fawzi (2011). Under-diagnosis of malnutrition in infants and young children in Rwanda: implications for attainment of the Millennium Development Goal to end poverty and hunger. *International Journal for Equity in Health*, 10: 61-67.

Caballero, B. (2005). A nutrition paradox — underweight and obesity in developing countries. *New England Journal of Medicine*, 352: 1514-1516.

Checkley, W., G. Buckley and R. H. Gilman (2008). Multi-country analysis of the effects of diarrhoea on childhood stun-ting. *International Journal of Epidemiology*, 37: 816-830

Chianese, J. (2005). Short stature. *Pediatrics in Review*, 26: 36-37.

Ferreira, H. S., T. M. Florêncio, E. F. Vieira and M. L. Assunção (2008). Stunting is associated with wasting in children from the semiarid region of Alagoas, Brazil. *Nutrition Research*, 28: 364-367

Flores-Mira, C., F. R. Mauriciob, M. F. Orellanad and P. W. Major (2005). Association between growth stunting with dental development and skeletal maturation stage. *Angle Orthodontics*, 75: 935-940.

Han, Z., S. Mulla, J. Beyene, G. Liao and S. D. McDonald (2011). Maternal underweight and the risk of pre-term birth and low birth weight: a systematic review and meta-analyses. *International Journal of Epidemiology*, 40: 65-101.

Krebs, N. .F, M. Mazareigos, A. Tshefu, C. Bose, N. Sami, E. Chomba, W. Carlo, N. Goco, M. Kindem, L. L.Wright, K. M. Hambidge and the Complementary Feeding Study Group (2011). Meat consumption is associated with less stun-ting among toddlers in four diverse low-income settings. *Food Nutrition Bulletin*, 32: 185-191.

Kamal, S. A. (2006). Manual for obtaining anthropometric measurements. *The-NGDS-Pilot-Project-e-Publi-cation*, University of Karachi, Karachi, Pakistan; full text: http://www.ngds-ku.org/ngds_folder/M02.pdf

Kamal S. A., C. M. S. Manzoor and S. A. Khan (2013*a*). Diet-based interventions and vitamin-D defi-ciency. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHROMATHE-MATICS2013)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p 14, abstract#Anthro13-08: http://www.ngds-ku.org/Presentations/VitaminD.pdf

Kamal S. A., C. M. S. Manzoor and S. A. Khan (2013*b*). Increasing height through diet, exercise and lifestyle adjustment. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHRO-MATHEMATICS2013)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p 18, abstract#Anthro13-12: http://www.ngds-ku.org/Presentations/Height_Management.pdf

Kamal, S. A., M. K. Rajput and S. A. Khan (2011*a*). 3-D-optical imaging in diabetic foot care of children. *Symposium on Diabetic Foot Care*, Department of Orthopedic Surgery, Najmuddin Auditorium, Jinnah Postgraduate Medical Center, Karachi, Pakistan, p 1, abstract: http://www.ngds-ku.org/Presentations/JPMC.pdf

Kamal, S. A., N. Jamil and S. A. Khan (2011*b*). Growth-and-obesity profiles of children of Karachi using box-inter-polation method. *International Journal of Biology and Biotechnology*, 8: 87-96, full text: http://www.ngds-ku.org/Papers/J29.pdf

Kamal S. A., S. Burki and S. S. Jamil (2013*c*). Optimal-weight management through diet, exercise and lifestyle adjustment. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHRO-MATHEMATICS2013)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p 9, abstract#Anthro13-03: http://www.ngds-ku.org/Presentations/Optimal_Weight.pdf

Kamal, S. A., S. Firdous and S. J. Alam (2004). An Investigation of growth profiles of the Pakistani children. *Inter-national Journal of Biology and Biotechnology*, 1: 707-717, full text: http://www.ngds-ku.org/Papers/J26.pdf

Kamal, S. A. and S. S. Jamil (2012). A method to generate growth-and-obesity profiles of children of still-growing parents. *International Journal of Biology and Biotechnology*, 9: 233-255, full text: http://www.ngds-ku.org/Papers/J30.pdf

Lawlor, D. A., D. A. Leon, F. Rasmussen (2007). Growth trajectory matters: interpreting the associations among birth weight, concurrent body size, and systolic blood pressure in a cohort study of 378,707 Swedish men. *American Journal of Epidemiology*, 165: 1405-1412.

Maiti, S., K. Chatterjee, K. M. Ali, D. Ghosh and S. Paul (2012). Stunting, underweight and overweight: A major health problem among children under 3 years of age in urban areas of West Bengal, India. *Serbian Journal of Experimental and Clinical Research* 13: 93-98.

Mamiro, P. S., p. Kolsteren, D. Roberfroid, S. Tatala, A. S. Opsomer and J. H. V. Camp (2005). Feeding practices and fac-tors contributing to wasting, stunting, and iron-deficiency anaemia among 3-23-month old children in Kilosa district, rural Tanzania. *Journal of Health and Popular Nutrition*, 23: 222-230.

Martorell, R. and M. F. Young (2012). Patterns of stunting and wasting: Potential explanatory factors. *Advances in Nutri-tion*, 3: 227-233.

Murage, E. W.K. , K. Kahn, J. M. Pettifor, S. M. Tollman, D. B. Dunger, X. F. G. Olive and S. A. Norris (2010). The pre-valence of stunting, overweight and obesity, and metabolic disease risk in rural South African children. *BMC Public Health*, 10: 158-171.

Onis, M. D., M. Blössner and E. Borghi (2003). Prevalence and trends of stunting among preschool children, 1990-2020. *Public Health Nutrition*, 349: 2184-2186.

Richard, S. A., R. E. Black, R. H. Gilman, R. L. Guerrant, G. Kang, C. F. Lanata, K. Molbak, Z. A. Rasmussen, R. B. Sack, P. V. Branth, W. Checkley and Childhood Infection and Malnutrition Network (2012) Wasting is associated with stunting in early childhood. *Journal of Nutrition*, 142: 1291-1296.

Stevens, G. A., M. M. Finucane, C. J. Paciorek, S. R. Flaxman, R. A. White, A. J. Donner, M. Ezzati, on behalf of Nutri-tion Impact Model Study Group (Child Growth) (2012). Trends in mild, moderate, and severe stunting and under-weight, and progress towards MDG 1 in 141 developing countries: a systematic analysis of population representative data. *Lancet*, 380: 824-834.

Tanner, J. M., H. Goldstein and R. H. Whitehouse (1970). Standards for children's height at ages 2-9 years allowing for height of parents. *Archives of Disease in Childhood*, 45: 755-762.

Walker, S. P., S. M. Chang, C. A. Powel, E. Simonoff, S. M. Grantham-McGregor (2007). Early childhood stunting is associated with poor psychological functioning in late adolescence and effects are reduced by psychosocial stimu-lation. *Journal of Nutrition*, 137: 2464-2469.

Subramanyam, M. A., I. Kawachi, L. F. Berkman and S. V. Subramanian (2011). Is economic growth associated with reduction in child under-nutrition in India? *PLoS Medicine*, 8: 01-15.

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