

Body Composition Response to Lower Body Positive Pressure Training in Obese Children

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Abstract—Background: The high prevalence of obesity in Egypt has a great impact on the health care system, economic and social situation. Evidence suggests that even a moderate amount of weight loss can be useful. **Aim of the study:** To analyze the effects of lower body positive pressure supported treadmill training, conducted with hypocaloric diet, on body composition of obese children. **Methods:** Thirty children aged between 8 and 14 years, were randomly assigned into two groups: intervention group (15 children) and control group (15 children). All of them were evaluated using body composition analysis through bioelectric impedance. The following parameters were measured before and after the intervention: body mass, body fat mass, muscle mass, body mass index (BMI), percentage of body fat and basal metabolic rate (BMR). The study group exercised with antigravity treadmill three times a week during 2 months, and participated in a hypocaloric diet program. The control group participated in a hypocaloric diet program only. **Results:** Both groups showed significant reduction in body mass, body fat mass and BMI. Only study group showed significant reduction in percentage of body fat ($p = 0.0043$). Changes in muscle mass and BMR didn't reach statistical significance in both groups. No significant differences were observed between groups except for muscle mass ($p = 0.049$) and BMR ($p = 0.042$) favoring study group. **Conclusion:** Both programs proved effective in the reduction of obesity indicators, but lower body positive pressure supported treadmill training was more effective in improving muscle mass and BMR.

Keywords—Children, Hypocaloric diet, Lower body positive pressure supported treadmill, obesity.

I. INTRODUCTION

OBESITY is a chronic and epidemic disease whose prevalence increased in the last decades in many countries, including Egypt. The World Health Organization has warned of the escalating epidemic of obesity that could put the population in many countries at risk of developing noncommunicable diseases (NCD). Available studies in Eastern Mediterranean countries (EMR) indicate that obesity has reached at an alarming level among both children and adults. Consequently, the incidence of NCD is also very high and represents more than 50% of total causes of death in the EMR [1], [2]. A systematic review of published papers between 1990 and 2011 showed that Obesity reached an alarming level in all age groups of the EMR countries including Egypt. The prevalence in school children ranged from 7% to 45% [3].

In addition to the high prevalence, the relevance of

childhood obesity has been increasing due to its association with several morbid conditions, such as diabetes mellitus type 2, hypertension, dyslipidemia, and atherosclerosis complications in adulthood [4].

Early endothelial dysfunction in obese children and adolescents, in which the carotid intima media thickness is significantly greater than those with normal weight, is also reported [5].

The relationship between obesity and metabolic syndrome appears to be especially important in childhood, since excess weight has been considered a predisposing factor for this syndrome even at this age, diagnosed in approximately 40% of obese children [6].

Pulmonary disorders, including obstructive sleep apnoea and reactive airway disease [7], are reported more frequently in obese children than in their normal-weight counterparts. Weight-related but non-asthmatic air flow limitations are perhaps being misdiagnosed as asthma in some obese children. [8] Specific nutritional deficiencies often accompany childhood obesity. Low vitamin D concentrations [9] and iron-deficiency [10] were reported.

The appropriate approach to reduce the obesity related health risk is to reduce body weight. As a basic component of prevention and treatment of obesity, the early adoption of a healthy lifestyle should be considered, such as a balanced diet and physical exercises, from childhood onwards [11].

Physical exercise programs and nutritional guidance have been proved effective in the treatment of obese children and adolescents [11], [12]. They have positive effects on the components of the metabolic syndrome [13]; and in reducing excess weight, fat body mass, abdominal perimeter, and blood pressure [14].

However, when working with children, structured physical exercise programs, although effective, may be less welcoming, receiving lower adherence.

Recently, a new treadmill was introduced that permits low-load walking using an emerging technology called lower body positive pressure (LBPP) [15]. The system utilizes a waist-high air chamber that can be inflated with positive air pressure in order to modify body weight during ambulation. During an exercise session, subjects wear a pair of neoprene shorts with a kayak-style skirt that zips into an air chamber, creating an airtight seal. When the air chamber inflates, there is an increase in air pressure around the lower body that creates a net lifting force on the user [15], [16]. This effectively reduces body weight and the gravitational forces about the lower extremity to a level that can be adjusted with a high degree of consistency [16], [17]. The amount of body weight supported

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is dependent upon the air pressure in the bag. Positive air pressure can then be used to accurately unweight a person by increments as small as 1% body weight and as large as 80% body weight [18].

Computer-regulated air pressure of less than 30mmHg supports around 50% of body weight [18] and makes it possible for the user to walk and run with less effort for a given speed [19]. The lower-body positive pressure also creates compressive forces on the vasculature of similar magnitude to compression stockings [20]. A system making use of lower-body positive pressure for weight-supported treadmill exercise (AlterG Anti-Gravity Treadmill) was recently approved by the US Food and Drug Administration (FDA) in 2008 [21] for clinical use in rehabilitative purposes of lower-body injuries and surgery, aerobic conditioning, weight control and reduction, sport-specific conditioning, and neurologic retraining [22].

Lower body positive pressure is recognized as being superior to other methods of weight supported exercise (such as aquatic exercises), because the air pressure is applied uniformly over the lower body, while maintaining normal muscle activation and gait patterns (which are altered during aquatic-based activities) [16], [19], [23]. As a result, the LBPP treadmill technology is gaining popularity as a device that offers the ability to study weight-supported or low-load exercise in a user-friendly and kinematically correct manner [16], [24], without altering gait dynamics [16] or cardiovascular parameters such as heart rate and blood pressure [17], [25].

To date, the use of this emerging technology with an obese child population has gone unreported within the literature, and the feasibility of utilizing the LBPP technology to induce weight loss and facilitate exercise in this patient population is unknown. Also, despite extensive research on childhood obesity, there remains a lack of clear scientific evidence on the roles of diet and exercise in weight control, especially in children [26]. Other studies of obese children have shown that a combined diet and exercise intervention program lasting a relatively short time – two [27], [28] or three [29] months – improved anthropometric (BMI and waist circumference) parameters. Given the outlined shortcomings, this study aimed to investigate the effects of a supervised physical exercise using LBPP supported treadmill training and/or hypocaloric diet program on body composition of obese children.

II. METHODS

A. Participants

The initial population of the study included children aged between 8 and 14 years old with a body mass index (BMI) percentile above the 95th percentile [30]. Children were recruited from Outpatient Clinic of Faculty of Physical Therapy, Cairo University and Resala charitable organization. The inclusion criteria were: obese children aged between 8 and 14 years old. Exclusion criteria were participating in any type of structured program for weight loss; or having any physical or mental disability that hinders participation in the

study and diabetes, heart, renal, or liver diseases. The study group comprised 15 children and the control group comprised 15 children, amounting to 30 obese children from both sexes assigned at random. Children from the control group followed a hypocaloric diet while the study group followed a hypocaloric diet plus lower body positive pressure supported treadmill training for 2 months. All children, from both groups, were instructed to keep their regular activities during the study period.

B. Evaluation

All anthropometric measurements were taken twice. The body height and weight of the participants were measured while they wore light clothing without shoes using weight and height scale (health scale, 70, made in china). Weight was measured to the nearest 0.1 kg, and height was measured to the nearest centimeter. Systemic blood pressure was measured in the supine position after the participants had been at rest for at least 15 minutes and resting heart rate was also measured. The body composition of each participant was analyzed using portable direct segmental multiple-frequency bioelectrical impedance body composition analyzer, the Inbody 230 (Biospace, Seoul, Korea). Body composition results included weight, body fat mass, muscle mass, body mass index (BMI), (BMI) percentile, percentage of body fat, basal metabolic rate (BMR), obesity degree, ideal body weight and impedance of each segment (both arms, trunk and both legs) per 2 frequencies (20 and 100 kHz).

The children were analyzed standing on the footpads, barefoot on a spring scale, wearing only shorts and shirts. The name, age, height, and gender were entered before the exam. Each child was asked to stand still while the device captures the weight, at which point the child was asked to place his hands around the handgrips. During the exam, which is painless, the child stands still and breathes normally.

C. Intervention Program

The intervention program consisted of hypocaloric diet and walking program on lower body positive pressure supported (LBPPS) treadmill for the study group and hypocaloric diet only for the control group for 2 consecutive months. For the study group, the intervention program took place in Medical Rehabilitation Center of Armed Forces, while for the control group; it took place in Resala charitable organization. The exercises were performed in three weekly sessions, with the duration of 50 minutes each, amounting to 24 sessions. Each session consisted of stretching/ warming up (5-10 minutes), a main part – lower body positive pressure supported treadmill training (30 minutes), and relaxation (5-10 minutes). A lower body positive pressure support was provided by a system that consisted of a treadmill that enclosed in a pressurized bag (G-Trainer Pro; Alter-G Inc., Fremont, CA, USA). The child wore a pair of neoprene shorts that were zipped into the bag, and the amount of body weight supported was dependent upon the bag's air pressurization. The air pressure was uniformly distributed over the lower body. Furthermore, no support was provided around the torso. The child was able to freely swing

her/his arms during the training sessions or had the option to hold on to handrails that were at the front of the treadmill. Visual feedback was provided with a mirror positioned on the right side of the treadmill perpendicular to the LBPPS system. The bag material does not allow the child to see the legs when looking down. However, the bag does have translucent material on the side panels that allows the therapist to see the child's lower limbs, and the mirror allowed the child to also see his/her stepping pattern. The general guidelines of the therapeutic prescription consisted of supporting 50% of the child's body weight. The speed of the treadmill was gradually increased until reaching 3km/h which is considered the minimum goal of target speed. Treadmill training was carried out aiming at achieving an intensity of 65% to 75% of the maximum heart rate [31], indirectly determined by the formula (maximum heart rate = $208 - 0.7 \times \text{age}$) [32]. For each training session, the child accumulated a total of 30 minutes of walking (not including breaks). To individually monitor the heart rate, the children wore heart rate monitors to ensure its maintenance within the recommended range. Rest breaks were provided as needed; however, the children were encouraged to walk as long as possible. At the end of all sessions, orientations on the importance of regular physical exercises were provided.

Regarding hypocaloric diet, some previous studies recommended diets of between 1500 and 1800 kcal/day in obese children who are still growing [33], [34]. The diet therapy principle in both groups assured that caloric intake was 500 kcal/day below daily requirements [28]. The low-calorie diet consisted of five balanced meals spread throughout the day. The diet comprised 15% protein, 55% carbohydrates and 30% lipids. Foods were selected, as far as possible, according to the subjects' usual dietary habits. A series of general recommendations were established focused on basic healthier eating habits: consume ≥ 5 servings of fruits and vegetables every day; minimize sugar-sweetened beverages such as sugar-added fruit juices; have more meals prepared at home rather than takeaway restaurant food; etc.

D. Ethical Consideration

The study protocol was explained in details for each candidate and caregiver before the initial assessment. Child caregiver who had accepted to participate in the study signed an informed written consent before enrollment. If the child was old enough, he/she was asked for consent. This study was approved by the ethical committee of the Faculty of Physical Therapy, Cairo University.

E. Statistical Methods

Data were stored and analyzed with the SPSS statistical package 18.0 (SPSS Inc., Chicago, Illinois). Test selection was based on evaluating the variables for normal distribution. In order to analyze the data obtained, descriptive statistical procedures were initially performed for variables of interest, with the calculation of the mean and standard deviation in the variables with parametric distribution, and median and interquartile range from those with non-parametric distribution. Paired and unpaired Student's t-tests were used

for data with regular distribution; Mann-Whitney's U test and the Wilcoxon test were used in the variables with nonregular distribution. Comparison between categorical data was performed using the Chi square test. A significance level $p < 0.05$ was adopted.

III. RESULTS

The average age (interquartile range) in the control group was 10.50 (8.5-12.5) years and in the study group was 11 (11-13) years ($p = 0.264$). Groups also did not differ in sex nominal variable before intervention ($P = 0.709$). The control group included 10 girls and 5 boys while the study group included 8 girls and 7 boys.

The comparative analysis of initial body composition parameters demonstrated that there were no statistically significant differences between the groups in the pre-test (unpaired t-test or Mann-Whitney's test). However, the post-test showed that the groups differed as to muscle mass ($p = 0.049$) and basal metabolic rate ($p = 0.042$), with higher values in the study group, representing more satisfactory results (see Tables I and II).

Tables I and II present the results of the two groups in the body composition analysis. The control group showed significant reduction in weight, BMI and body fat after the end of the program. No significant differences were observed regarding the remaining variables. The study group also, presented a significant reduction in weight, BMI and body fat, as well as a reduction in body fat percentage (Table I). Although non significant, the muscle mass and BMR were increased (Table II). Data in the Table I indicate that the reduction in weight, body fat and BMI was observed in both groups; however, the reduction in the study group was much higher when compared to the control group.

TABLE I
STATISTICAL ANALYSIS OF BODY COMPOSITION PARAMETERS WITHIN EACH GROUP AND BETWEEN GROUPS

Item	Groups	Before	After	P1-value
Weight (Kg)	Control	61.6 (50.58-73.08)	60.25 (48.5-70.93)	0.017*
	Study	80.40 (67.40-83.85)	74.60 (62.5-78.95)	0.043*
	P ² -value	0.092	0.143	
BMI (Kg/m ²)	Control	28.60 (25.85-33.25)	26.45 (24.08-32.1)	0.017*
	Study	32.20 (28.20-32.6)	29.90 (26.35-30.45)	0.041*
	P ² -value	0.464	0.464	
Body Fat (Kg)	Control	28.58 (21.75-34.78)	28.05 (20.9-33.88)	0.018*
	Study	39 (28.8-41.35)	34.4 (2.75-37.05)	0.043*
	P ² -value	0.107	0.558	
Percentage of body fat (%)	Control	42.95 (41.43-49.03)	42.85 (41.2-49.63)	0.674
	Study	48.10 (41.65-49.55)	45.1 (33.05-47.55)	0.043*
	P ² -value	0.464	0.558	

Data are presented as median (interquartile range).

Kg= Kilogram, BMI= body mass index, Kg/m²= Kilogram per meter square; P1-value= difference within each group before and after the intervention, P2-value= difference between groups at baseline and after the intervention period; *Statistically significant difference (Mann-Whitney's U test and the Wilcoxon test).

TABLE II
RESULTS REGARDING MUSCLE MASS AND BASAL METABOLIC RATE WITHIN EACH GROUP AND BETWEEN GROUPS

Item	Groups	Before	After	P1-value
Muscle mass (Kg)	Control	18.21 ± 4.62	17.64 ± 4.24	0.107
	Study	22.02 ± 1.81	22.62 ± 3.38	0.621
	P ² -value	0.110	0.049*	0.110
BMR (Kcal)	Control	1111.13 ± 169.64	1092.13 ± 157.37	1111.13 ± 169.64
	Study	1249.60 ± 68.37	1266.20 ± 113.843	1249.60 ± 68.37
	P ² -value	0.114	0.042*	0.114

The data represent mean + standard deviation.

Kg= Kilogram, BMR= Basal metabolic rate, Kcal= Kilo calorie; P1-value= difference within each group before and after the intervention, P2-value= difference between groups at baseline and after the intervention period; *Statistically significant difference (Paired and unpaired Student's t-test).

IV. DISCUSSION

Childhood obesity can adversely affect almost every organ system and often has serious consequences [35].

The treatment of obesity remains difficult. Certain effective drug therapies have been withdrawn from the market because of dangerous cardiovascular effects [36], and therefore medical treatment of obesity is currently not available for overweight or obese children. Non pharmacological measures such as diet and exercise therefore represent the mainstays of obesity prevention and treatment in developed and developing countries [37].

A catabolic state of stored energy is needed to induce weight loss. Guidelines from the American Academy of Pediatrics recommend that weight-reducing diets contain "less energy than that required maintaining weight but not less than 1200 kilocalories a day" [38]. The equivalent UK guidance emphasizes energy balance between intake and expenditure, but does not specify amounts of intake [39]. Another recommended approach is to construct a diet that is 300–400 kcal per day lower than the weight-maintenance requirements as assessed by dietary history or as calculated on the basis of a formula relating anthropometry to energy expenditure, such as

the Harris-Benedict equation. In view of the magnitude of the energy gap, a sizeable energy deficit would be needed to induce appreciable weight reductions in an obese child, and many weight-loss diets might be energy neutral in young children or even lead to weight gain in sedentary female adolescents [40], [41].

Lower body positive pressure supported treadmill exercise offers an attractive option to more traditional exercise modes that have been used to limit lower-extremity loading forces.

The present study analyzed the effects on body composition of an intervention based on lower body positive pressure supported treadmill training on anti-gravity treadmill and/or a hypocaloric diet program in obese children.

The intervention based solely on a hypocaloric diet (control group), achieved significant reduction in the body composition parameters except body fat percentage, muscle mass and basal metabolic rate which showed a non significant reduction after the two-month program. Similar results were found in another intervention of longer duration (12 weeks) and similar diet (1200 kcal/day) significantly reduced the BMI and body fat percentage. Weight loss was greater in the diet or diet-plus-exercise group (being similar in these two) than in the exercise-only group [29]. In contrast, another study of shorter

duration (six weeks), but of greater dietary restriction (900 and 1200 kcal/day) didn't find any significant changes in weight, BMI, fat mass, fat free mass and fat percentage [42]. It is possible that these differences may be attributed to the total duration of the program, caloric restriction and initial body fat distribution.

In the intervention which combined LBPP supported treadmill training and a hypocaloric diet (study group), a significant reduction was observed in body composition parameters, with a nonsignificant increase in muscle mass and basal metabolic rate. These results agree with those of a previous study of longer session (90 min/day), higher frequency (four days a week) and individual diet (-500 kcal/day below the initial dietary records). Their exercise program included a running, jumping and ball games [28]. Both studies show that a combined program of exercise and a hypocaloric diet contributes effectively to the prevention of obesity in children, probably because this strategy increases fat oxidation during exercise [43]. In this regard, a combination therapy of diet plus exercise develops aerobic capacity, thus improving glucose tolerance and the lipoprotein profiles, and reducing the risk of coronary heart disease [44] which could be measured in future research, especially that promotion of increased energy expenditure for weight reduction has not received the same attention as have dietary prescriptions.

Regarding inter group differences, the results showed that children benefited more from the combined program than the hypocaloric diet alone by better managing their body composition. In particular, LBPP supported treadmill training group succeeded to gain significant difference in muscle mass and basal metabolic rate over hypocaloric diet alone despite failure to find a statistical significance increase in these two variables intra group which appears to be especially important to child's health. This is a positive finding since [45] had suggested that a combination of dietary and exercise programs for obese children facilitates the selective reduction of body fat, while maintaining the amount of muscle of the entire body.

Our study has some limitations. The duration of the intervention was only two months without follow up. Indeed, this was a pilot study for a subsequent longitudinal analysis of the body composition being monitored over the following months. One of the limitations of this study was the relatively small sample size. Studies with a higher number of children may bring important contributions to the behavior of such variables. However, the sample may be considered acceptable for the purposes of the present work since there have been studies in this area working with samples of similar sizes or even lower [27], [28]. Inclusion of an exercise only group, a nonintervention (with no change in lifestyle) group of obese children, and a non obese, sedentary group may also have provided further information; however, we thought it was difficult to recruit such subjects, particularly without dietary advice also.

V.CONCLUSION

To our knowledge, this is the first clinical report on the recently developed AlterG Anti-Gravity treadmill in weight control of obese children. While the potential use of the system for various lower-extremity disabilities is apparent, this case demonstrates a particularly novel application proven effective in improving body composition in obese children.

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REFERENCES

- [1] A. O. Musaiger, "Overweight and obesity in the Eastern Mediterranean Region: can we control it?," *East. Mediterr. Health J.*, vol. 10, no. 6, pp. 789–793, Nov. 2004.
- [2] A. M. Sibai, L. Nasreddine, A. H. Mokdad, N. Adra, M. Tabet, and N. Hwalla, "Nutrition transition and cardiovascular disease risk factors in Middle East and North Africa countries: reviewing the evidence," *Ann. Nutr. Metab.*, vol. 57, pp. 193–203, Nov. 2010.
- [3] A. O. Musaiger, "Overweight and obesity in eastern mediterranean region: prevalence and possible Causes," *J. Obes.*, vol. 2011, Article ID 407237, 17 pages, doi: 10.1155/2011/407237, Sep. 2011.
- [4] T. Reinehr, R. Wunsch, G. Sousa, and A. M. Toschke, "Relationship between metabolic syndrome definitions for children and adolescents and intima-media thickness," *Atherosclerosis*, vol. 199, no. 1, pp. 193–200, Jul. 2008.
- [5] S. K. Pasquali, and M. S. Cohen, "The impact of obesity in children with congenital and acquired heart disease," *Prog. Pediatr. Cardiol.*, vol. 25, pp. 119–24, 2008.
- [6] R. Weiss, J. Dziura, T. S. Burgert, W. V. Tamborlane, S. E. Taksali, C. W. Yeckel, *et al.*, "Obesity and the metabolic syndrome in children and adolescents," *N. Engl. J. Med.*, vol. 350, no. 23, pp. 2362–74, Jun. 2004.
- [7] F. D. Gilliland, K. Berhane, T. Islam, R. McConnell, W. J. Gauderman, S. S. Gilliland *et al.*, "Obesity and the risk of newly diagnosed asthma in school-age children," *Am. J. Epidemiol.*, vol. 158, no. 5, pp. 406–15, Sep. 2003.
- [8] E. R. Sutherland, "Obesity and asthma," *Immunol. Allergy Clin. North Am.*, vol. 28, no. 3, pp. 589–602, ix, Aug. 2008.
- [9] R. Alemzadeh, J. Kichler, G. Babar, and M. Calhoun, "Hypovitaminosis D in obese children and adolescents: relationship with adiposity, insulin sensitivity, ethnicity, and season," *Metabolism*, vol. 57, no. 2, pp. 183–91, Feb. 2008.
- [10] K. G. Nead, J. S. Halterman, J. M. Kaczorowski, P. Auinger, and M. Weitzman, "Overweight children and adolescents: a risk group for iron deficiency," *Pediatrics*, vol. 114, no. 1, pp. 104–08, Jul. 2004.
- [11] L. S. Poeta, F. Duarte Mde, B. Caramelli, M. Jorge, and C. Giuliano Ide, "Effects of physical exercises and nutritional guidance on the cardiovascular risk profile of obese children," *Rev. Assoc. Med. Bras.*, vol. 59, no. 1, pp. 56–63, 2013.
- [12] N. Leite, G. E. Milano, F. Cieslak, W. A. Lopes, A. Rodacki, and R. B. Radominski, "Effects of physical exercise and nutritional guidance on metabolic syndrome in obese adolescents," *Rev. Bras. Fisioter.*, vol. 13, pp. 73–81, 2009.
- [13] R. Monzavi, D. Dreimane, M. E. Geffner, S. Braun, B. Conrad, M. Klier, *et al.*, "Improvement in risk factors for metabolic syndrome and insulin resistance in overweight youth who are treated with lifestyle intervention," *Pediatrics*, vol. 117, no. 6, pp. e1111–8, Jun. 2006.
- [14] T. Reinehr, A. Shaefer, K. Winkel, E. Finne, A. M. Toschke, and P. Kolip, "An effective lifestyle intervention in overweight children: findings from a randomized controlled trial on "Obeldicks light", " *Clin. Nutr.*, vol. 29, no. 3, pp. 331–6, Jun. 2010.
- [15] R. K. Eastlack, A. R. Hargens, E. R. Groppo, G. C. Steinbach, K. K. White, and R. A. Pedowitz, "Lower body positive-pressure exercise after knee surgery," *Clin. Orthop. Relat. Res.*, vol. 431, pp. 213–219, Feb. 2005.
- [16] E. J. Quigley, H. Noh, and E. R. Groppo, "Gait mechanics using a lower body positive pressure chamber for orthopaedic rehabilitation," *Trans. Orthop. Res. Soc.*, vol. 25, pp. 828, 2000.

- [17] A. Hargens, A. Cutuk, K. White, "Cardiovascular impact of lower body positive pressure," *Med. Sci. Sports Exerc.*; 31 (1S), 1999.
- [18] A. Cutuk, E. R. Groppo, E. J. Quigley, K. W. White, R. A. Pedowitz, and A. R. Hargens, "Ambulation in simulated fractional gravity using lower body positive pressure: cardiovascular safety and gait analyses," *J. Appl. Physiol.*, vol. 101, no. 3, pp. 771–777, Sep. 2006.
- [19] A. M. Grabowski, and R. Kram, "Effects of velocity and weight support on ground reaction forces and metabolic power during running," *J. Appl. Biomech.*, vol. 24, no. 3, pp. 288–97, Aug. 2008.
- [20] J. C. Veraart, E. Daamen, H. C. de Vet, and H. A. Neumann, "Elastic compression stockings: durability of pressure in daily practice," *Vasa*, vol. 26, no. 4, pp. 282–6, Nov. 1997.
- [21] U.S. Food and Drug Administration Medical Devices 510 (k) Clearances #K072887 (2008). Last updated Aug. 5, 2009. Retrieved Jan. 17, 2011, from [http://www.fda.gov/MedicalDevices/Products and Medical Procedures/Device Approvals and Clearances/ 510k Clearances/ ucm081816 .htm](http://www.fda.gov/MedicalDevices/Products%20and%20Medical%20Procedures/Device%20Approvals%20and%20Clearances/510k%20Clearances/ucm081816.htm).
- [22] M. N. Moore, C. Vandenakker-Albanese, and M. D. Hoffman, "Use of partial body-weight support for aggressive return to running after lumbar disk herniation: A case report," *Arch. Phys. Med. Rehabil.*, vol. 91, pp. 803–5, May 2010.
- [23] J. Liebenberg, J. Scharf, D. Forrest, J. S. Dufek, K. Masumoto, and J. A. Mercer, "Determination of muscle activity during running at reduced body weight," *J. Sports. Sci.*, vol. 29, no. 2, pp. 207–214, Jan. 2011.
- [24] S. Patil, N. Steklov, W. D. Bugbee, T. Goldberg, C. W. Colwell, Jr., and D. D. Lima, "Anti-gravity treadmills are effective in reducing knee forces," *J. Orthop. Res.*, vol. 31, no. 5, pp. 672–679, May 2013.
- [25] B. Gojanovic, P. Cutti, R. Shultz, and G. O. Matheson, "Maximal physiological parameters during partial body-weight support treadmill testing," *Med. Sci. Sports. Exerc.*, vol. 44, no. 10, pp. 1935–1941, Oct. 2012.
- [26] C. Maffei, and M. Castellani, "Physical activity: an effective way to control weight in children?," *Nutr. Metab. Cardiovasc. Dis.*, vol. 17, no. 5, pp. 394–408, Jun. 2007.
- [27] O. Ben Ounis, M. Elloumi, I. Ben Chiekh, A. Zbidi, M. Amri, G. Lac, *etal.*, "Effects of two-month physical endurance and diet-restriction programmes on lipid profiles and insulin resistance in obese adolescent boys," *Diabetes Metab.*, vol. 34, no. 6Pt 1, pp. 595–600, Dec. 2008.
- [28] M. Elloumi, O. Ben Ounis, E. Makni, E. Van Praagh, Z. Tabka, and G. Lac, "Effect of individualized weight-loss programmes on adiponectin, leptin and resistin levels in obese adolescent boys," *Acta Paediatr.*, vol. 98, no. 9, pp. 1487–1493, Sep. 2009.
- [29] S. Shalitin, L. Ashkenazi-Hoffnung, M. Yackobovitch-Gavan, N. Nagelberg, Y. Karni, E. HersHKovitz *etal.*, "Effects of a twelve-week randomized intervention of exercise and/or diet on weight loss and weight maintenance, and other metabolic parameters in obese preadolescent children," *Horm. Res.*, vol. 72, no. 5, pp. 287–301, 2009.
- [30] CDC, "Healthy Weight - it's not a diet, it's a lifestyle!," Developed by Division of Nutrition, Physical Activity, and Obesity, National Center for Chronic Disease Prevention and Health Promotion, 2011. Available from: http://www.cdc.gov/healthyweight/assessing/bmi/childrens_BMI/about_childrens_BMI.html.
- [31] K. Watts, P. Beye, A. Siafarikas, G. O'Driscoll, T. W. Jones, E. A. Davis, *etal.*, "Effects of exercise training on vascular function in obese children," *J. Pediatr.*, vol. 144, no. 5, pp. 620–5, May 2004.
- [32] H. Tanaka, K. D. Monahan, and D. R. Seals, "Age-predicted maximal heart rate revisited," *J. Am. Coll. Cardiol.*, vol. 37, no. 1, pp. 153–6, Jan. 2001.
- [33] C. Braet, A. Tanghe, P. De Bode, H. Franckx, and M. Van Winckel, "Inpatient treatment of obese children: a multicomponent program without stringent calorie restriction," *Eur. J. Pediatr.*, vol. 162, no. 6, pp. 391–396, Jun. 2003.
- [34] C. E. Flodmark, "Management of obese child using psychological-based treatments," *Acta Paediatr.*, vol. 94, no. Suppl. 448, pp. 14–28, Jun. 2005.
- [35] J. C. Han, D. A. Lawlor, and S. Y. Kimm, "Childhood obesity," *Lancet*, vol. 375, no. 9727, pp. 1737–48, May 2010.
- [36] H. M. Connolly, J. L. Crary, M. D. McGoon, D. D. Hensrud, B. S. Edwards, W. D. Edwards *etal.*, "Valvular heart disease associated with fenfluramine-phentermine," *N. Engl. J. Med.*, vol. 337, no. 9, pp. 581–588, Aug. 1997.
- [37] K. S. Woo, P. Chook, C. W. Yu, R. Y. Sung, M. Qiao, S. S. Leung, *etal.*, "Effects of diet and exercise on obesity-related vascular dysfunction in children," *Circulation*, vol. 109, no. 16, pp. 1981–1986, Apr. 2004.
- [38] B. A. Spear, S. E. Barlow, C. Ervin, D. S. Ludwig, B. E. Saelens, K. E. Schetzina, *etal.*, "Recommendations for treatment of child and adolescent overweight and obesity," *Pediatrics*, vol. 120, no. suppl. 4, pp. S254–88, Dec. 2007.
- [39] National Institute for Health and Clinical Excellence, "Obesity: the prevention, identification, assessment and management of overweight and obesity in adults and children," 2006 <http://www.nice.org.uk/guidance/index.jsp?action=byID&o=11000>.
- [40] N. F. Butte, and K. J. Ellis, "Comment on Obesity and the environment: where do we go from here?," *Science*, vol. 301, no. 5633, pp. 598, Aug. 2003.
- [41] J. O. Hill, H. R. Wyatt, G. W. Reed, and J. C. Peters, "Obesity and the environment: where do we go from here?," *Science*, vol. 299, no. 5608, pp. 853–55, Feb. 2003.
- [42] R. Y. Sung, C. W. Yu, S. K. Chang, S. W. Mo, K. S. Woo, and C.W. Lam, "Effects of dietary intervention and strength training on blood lipid level in obese children," *Arch. Dis. Child.*, vol. 86, no. 6, pp. 407–410, Jun. 2002.
- [43] G. Rodriguez, and L. A. Moreno, "Is dietary intake able to explain differences in body fatness in children and adolescents?," *Nutr. Metab. Cardiovasc. Dis.*, vol. 16, no. 4, pp. 294–301, May 2006.
- [44] T. Reinehr, G. de Sousa, A. M. Toschke, and W. Andler, "Long-term follow-up of cardiovascular disease risk factors in children after an obesity intervention," *Am. J. Clin. Nutr.*, vol. 84, no. 3, pp. 490–496, Sep. 2006.
- [45] K. Watts, T. W. Jones, E. A. Davis, and D. Green, "Exercise training in obese children and adolescents: current concepts," *Sports Med.*, vol. 35, no. 5, pp. 375–392, 2005.