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EFFECTS OF LOWER EXTREMITY STRENGTH TRAINING ON GAIT PATTERNS IN OBESE CHILDREN

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The purpose of this study was to investigate the effect of muscle strength training on gait patterns in obese children. This study included 14 obese children who were required to complete 8 week lower extremity strength training. All participants went through a 3D gait analysis and an isokinetic strength test before and after training. With the improvement in muscle strength, walking speed and stride length significantly increased after intervention. Hip flexion moment and hip power generation increased 31.1% and 22.4%, respectively. Hip and knee power absorption also significantly increased. We concluded that the strength training improved obese children's ability to promote locomotion through greater propulsion. Muscle strength plays an important role in attenuating the negative effects that obesity has on gait characteristics and kinetics.

KEY WORDS: strength training, gait, obesity

INTRODUCTION: Studies showed obesity is associated with more musculoskeletal discomfort, injuries, inefficient body mechanics and further reductions in mobility (Wearing *et al.*, 2006). Some studies have demonstrated overweight and obesity have negative impact on maintain balance and gait (Hills & Parker, 1992; Macfarlane *et al.*, 2011; McGraw *et al.*, 2000). McMillan et al. (2010) extended that the abnormal gait patterns, which were different from normal-weight children, may be caused by muscle weakness. Although obese children are expected to represent a higher muscle strength and power, studies have consistently reported worse performance in the obese in whole body movements (Deforche *et al.*, 2003). Obese children were required more muscle forces to move their greater mass against gravity and maintain the stability of lower limb. Therefore, insufficient muscular strength and power could limit an individual's ability to successfully perform daily tasks involving lower limb strength and power (Dumitrescu *et al.*, 2010). The purpose of this study was to investigate the effect of muscle strength training on gait patterns in obese children.

METHODS: This study included 14 children (7 boys, 6 girls), aged 10-12, who have body mass index (BMI, in kg.m^2) level above age and gender specific cut-off points for obesity defined by Cole et al.(2007). All participants were required to complete three sessions lower extremity strength training per week for 8 weeks. Each session took about 45 minutes under the supervision by qualified trainers. This intervention program conditions the body through dynamic, resistance exercises. The elastic bands were used to create resistance. The type of training typically includes internal/external rotation, abdominal/abduction and flexion/extension movements of hip, knee, ankle joints. All participants and their parents or guardians read and signed an informed consent form approved by the University of Auckland's Human Research Ethics committee.

All participants went through a 3D gait analysis at the Biomechanics Laboratory. The ground reaction forces and 3D kinematic parameters during walking were recorded by two Kistler forceplates (Kistler Instrumente AG, Winterthur, Switzerland) with a sampling rate of 1000Hz, and a 16-camera VICON digital video-based motion analysis system (Vicon Oxford Metrics, Oxford, UK) with a sampling rate of 100Hz, respectively. Participants were asked to walk along a 15m walkway at their self-preferred speed. A set of spherical reflective markers of diameter 14mm were attached to each child based on the Cleveland Clinic marker set (OrthoTrak 4.2 Reference Manual, Motion Analysis Corporation, Santa Rosa, CA, USA). An inverse dynamics procedure was then performed to calculate joint moments and powers at all joints using Vicon Nexus Software (Oxford Metrics, Oxford, UK). Maximal isokinetic tests for knee and ankle flexion/extension muscle strength were performed on a Con-Trex multi joint isokinetic dynamometer (CMV AG, Dübendorf, Switzerland). After a low-intensity warm-up, leg and foot flexion and extension exercises were carried out using the angular velocity of 60 degree/s.

Means and standard deviations of measured parameters were calculated for each group. A paired t-test was utilized to determine the simple difference between baseline and after intervention for each group. A p-value of <0.05 was considered to be statistically significant. All data were analyzed using the statistical package for the social sciences (SPSS, version 15.0, SPSS Inc, Chicago, IL).

RESULTS: The results of anthropometry parameters and isokinetic muscle strength were presented in Table 1. There was no statistically significant change in body height, weight and BMI. The isokinetic muscle strength significantly improved after intervention. The peak torque of the knee flexor and extensor increased 16.1% and 9.2%, respectively. The peak torque of ankle flexor and extensor increased 16.2% and 13.8%, respectively.

Table 1

Anthropometry parameters and muscle strength (joint peak torque at 60°/s rate) before and after intervention (means ± SD)

Index	Before	After	p
Height (cm)	152.1±4.5	152.8±4.2	0.258
Weight (kg)	61.2±4.4	62.1±5.1	0.089
BMI (kg/m^2)	26.4±1.5	26.5±1.3	0.281
Knee Flexor (Nm)	49.0±11.6	56.9±10.5	0.023
Knee Extensor (Nm)	76.8±14.9	83.9±15.3	0.009
Ankle Flexor (Nm)	49.4±12.3	57.4±13.6	0.003
Ankle Extensor (Nm)	17.4±2.9	19.8±2.9	0.005

The temporal-spatial parameters of the gait cycle were shown in Table 2. The walking speed was 5.0% faster compared to baseline. The stride length also significantly increased. No statistical improvements were seen for the other gait parameters.

Table 2

Temporal-spatial gait parameters (means ± SD)

Index	Before	After	p
Speed (m/s)	1.19±0.07	1.25±0.07	0.011
Cadence (step/min)	121.6±6.3	122.3±5.9	0.707
Step width (cm)	17.2±3.2	16.7±2.8	0.515
Stride length (m)	1.22±0.09	1.25±0.06	0.020
Double support (%)	16.2±2.6	16.1±2.7	0.817
Single support (%)	41.4±2.4	41.4±2.2	0.920
Stand Phase (%)	58.2±1.2	58.2±0.9	0.981

The comparisons of joint angle, flexion/extension moment and joint power over 100% gait cycle between baseline and after 8 weeks were presented in Figure 1. The peak value of hip flexion moment increased from 0.90±0.18 Nm/kg to 1.18±0.14 Nm/kg (p<0.01). The knee extension moment increased by 18.7% during preswing (p=0.021). Hip power absorption during midstance significantly increased from 0.64±0.13 W/kg to 0.79±0.14 W/kg. (p<0.01) after intervention, while a 22.9% improvement in knee power absorption was found during preswing. The hip power generation also increased significantly from 0.85±0.23 W/kg to 1.04±0.23 W/kg during preswing and initial swing (p<0.01). No significant change was seen in joint angles.

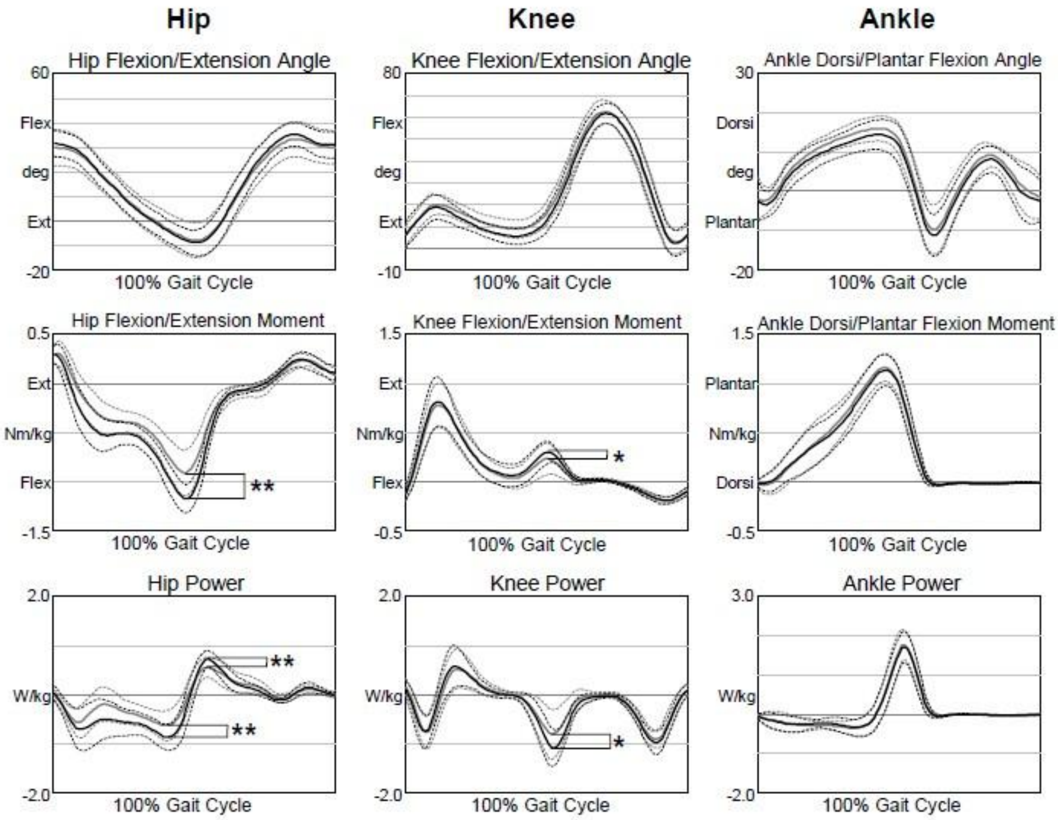

Figure 1: Lower extremity joint power, sagittal plane joint angle and moment over 100% gait cycle before (grey) and after intervention (black). Solid lines = mean, dotted lines = SD. *p<0.05, **p<0.01.

DISCUSSION: The majority of exercise intervention with obese children to date has focused on the weight-reducing efficacy or cardiovascular benefits of this type of training rather than the potential musculoskeletal health benefits. To the best of our knowledge, this is the first study to investigate the effect of lower extremity muscle strengthening on obese children's gait biomechanics.

All subjects were walking at self-selected walking pace, which allowed us to determine if muscle strengthening could change their natural gait patterns. In our study, the self-selected walking speed significantly increased after muscle strength training. Walking speed is an simple indicators of gait abnormalities associated with musculoskeletal problems. Previous studies also showed that obese children walked with shorter step length, lower cadence and velocity (Hills & Parker, 1991; McGraw, *et al.*, 2000). Thus, the result suggested obese children could perform more similar to normal gait after muscle strengthening. In addition, the changes of temporal-spatial gait parameters in obese children were considered to be a gait adaptive strategy driven by excess body weight (Hills & Parker, 1991). Our result also suggested that muscle strength can also contribute to the difference between obese and normal weight individual.

Concentric activity in the hip flexors is one of the primary sources for generating propulsion into the swing phase during gait cycle (Olney *et al.*, 1990). The increased hip flexion moment and power generation suggested the strength training improved participants' ability to promote locomotion through greater propulsion at "pull-off". Obese children were required to produce larger sagittal plane joint powers to control the trunk and prevent the collapse of the lower limb. Evidence showed that obese adolescents had poorer balance than normal weight children (Goulding *et al.*, 2003). Poor power generation in lower extremity may increase the risk for falling during daily activities. Our result suggested that muscle strengthening in lower extremity could also improve the balance and the ability to halt their forward progress once they begin to fall. This finding agrees with the results from Jadelis et al, who reported stronger knee extensor and flexor strength was associated with better balance (Jadelis *et al.*, 2001). Ankle plantarflexors provide support and propulsion during level walking. Humans can reorganize their neuromuscular function to increase ankle muscle function, plantarflexor torque, and ankle power with increased body weight during walking (DeVita & Hortobagyi, 2003). In our study, the increased ankle muscle strength has no effect on ankle moment and power during walking. Body weight may play a more important role in ankle kinetics than muslce strengthening.

CONCLUSION: The strength training improved obese children's ability to promote locomotion through greater propulsion. Muscle strength plays an important role in attenuating the negative effects that obesity has on gait characteristics and kinetics.

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