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Effect of maternal weight during pregnancy on offspring muscle strength response to resistance training in late adulthood

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ABSTRACT

Purpose: Maternal obesity can unfavorably influence offspring body composition, muscle strength, and possibly muscle's adaptability to training, but the human studies are scarce. Therefore, we aimed to investigate the effect of maternal obesity on offspring muscle strength responses to resistance training intervention in elderly frail women.

Materials/methods: Recruited participants were elderly frail women offspring of lean/normal weight mothers ($n = 19$, mean body mass index (BMI): 22.8 kg/m^2, range: 19.9–24.5) or overweight/obese mothers ($n = 16$, mean BMI: 29.7 kg/m^2, range: 28.2–34.2). Information on maternal BMI immediately prior to delivery was collected from the birth registers. All women participated in a 4-month supervised progressive resistance training intervention three times a week for 60 min. Predicted 1-RM of abdominal crunch, hip abduction, leg curl, leg press, seated row, and total strength were measured at baseline and after each month of training.

Results: According to rANOVA, strength increased significantly in both groups (p for time < 0.001), but no significant between the group difference were detected (p for time x group interaction > 0.072). On average, muscle strength of the women offspring of overweight/obese mothers tended to be lower than in women offspring of lean/normal weight mothers, but the only significant difference was found in leg curl ($p = 0.006$). No significant differences between the groups were found in relative strength changes from baseline to 4-months.

Conclusions: Muscle strength response to supervised resistance training is not modulated by maternal adiposity in late pregnancy in elderly frail female offspring.

1. Introduction

The Developmental Origins of Health and Disease (DOHaD) hypothesis proposes that environmental exposures during sensitive periods of development can result in phenotypic alterations affecting later health and disease susceptibility [1]. The prenatal period is associated with rapid cell division and is one of the most sensitive time periods in relation to developmental programming. In fact, recent evidence suggests that maternal adiposity during pregnancy can hamper offspring's skeletal muscle development [2] and increase the long-term risk for obesity, cardiovascular disease, type 2 diabetes [3–5].

Key stages of skeletal muscle development occur during early embryonic stage, mid pregnancy, and postnatally [6–8]. Especially, the mid gestational period can have long-term consequences to offspring muscle strength and function [9]. During this period, the maternal obesity-induced inflammation can drive the differentiation of mesenchymal stem cells (MSCs) into adipocytes rather than myocytes [10]. Maternal obesogenic environment can also increase intramyocellural fat accumulation in offspring, decrease skeletal muscle cross-sectional area [11], and muscle strength [12]. Although the exact mechanisms that explain the effect of maternal obesity and/or obesogenic environment on offspring muscle strength are unknown, the maternal obesity-induced inflammation could play a role. According to previous evidence, maternal obesity can decrease myogenesis by upregulating inflammatory IKK/NF-B signaling pathway and subsequently inhibiting Wnt/β-catenin signaling pathway [13]. β-catenin can have a

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critical role in the growth of adult's skeletal muscles after mechanical overload [14,15].

Interestingly, in human studies, maternal obesity has also been associated with increased concentration of inflammatory markers, e.g. interleukin-6 and C-reactive protein, in the cord blood [16]. Furthermore, in some human studies, but not in all [4], exposure to maternal adiposity has been associated with decreased fat free mass and increased fat mass in offspring [17,18]. This can lead into accumulation of intramuscular fat, which has been associated with decreased walking speed and grip strength in the elderly subjects [19]. Due to the link between the maternal obesity, inflammation and β-catenin, we hypothesized that elderly frail women offspring of overweight or obese mothers (OOM) can have compromised muscle strength response to resistance training compared to elderly frail women offspring of lean/normal weight mothers (OLM). Therefore, the purpose of this study was to compare the muscle strength changes between elderly frail women OLM and OOM after a 4-month supervised resistance training.

2. Patients and methods

2.1. Participants

Thirty-five elderly frail women (age 72.3 ± 3.2 years) from the clinical Helsinki Birth Cohort Study (HBCS) ($n = 2003$) were recruited for this study. Only women were recruited as the main aim of this study project was to investigate the association between risk factors of type 2 diabetes (e.g. insulin resistance) and the ageing process specifically in frail women. Recruited women were either offspring of mothers who belonged to the lowest body mass index (BMI) quartile ($\text{BMI} \leq 26.3\,\text{kg/m}^2$, $n = 19$) or the highest BMI quartile ($\text{BMI} \geq 28.1\,\text{kg/m}^2$, $n = 16$) at the time of the delivery. Study population specific quartiles, rather than the traditional BMI categories for normal weight ($< 25.0\,\text{kg/m}^2$), overweight ($25–29.9\,\text{kg/m}^2$), or obesity ($\geq 30\,\text{kg/m}^{2)}$ were applied to consider for the possible role of gestational weight gain. During pregnancy, normal weight women would gain approximately 11.5–16 kg, which could change the traditional BMI category from normal to overweight. Thus, applying $25\,\text{kg/m}^2$ as a criterion for overweight in late pregnancy may not be feasible. The maternal BMI thresholds were based on the data from all the mothers from the HBCS ($n = 13345/2003$). To retrieve information on maternal BMI, we first collected maternal body height and weight from the hospital records. The body height and weight information were then used to calculate maternal BMI at the time of the delivery as weight in kg divided by height in meters squared. Handgrip strength was used as the criterion for frailty [20]. The study participants (offspring) were considered frail if they belonged to the lower half of handgrip strength category within the HBCS study population. Data for handgrip strength measurements were obtained from the clinical examinations conducted between the years 2001 and 2004 [21]. Participants were excluded if they were currently smoking, had insulin treated diabetes, comorbidities that affected insulin sensitivity, or contraindications for participating in a resistance training intervention (e.g. chronic atrial fibrillation and pacemaker). The study was approved by the Ethics Committee of the Hospital District of Southwestern Finland (26/180/2012), and previously HBCS has been approved by the Ethics Committee of Epidemiology and Public Health of the Hospital District of Helsinki and Uusimaa (Helsinki, Finland) (344/E2/2000), and the National Public Health Institute (Helsinki, Finland). Written informed consent was obtained from all participants.

2.2. Intervention

The study participants were invited to participate in a 4-month supervised resistance training three times a week for 60 min. Training sessions consisted of 10 min of warm-up with cycle and/or elliptical ergometers and 8 different resistance exercises targeting large muscle groups of the upper and lower body (leg press, chest press, seated row, abdominal crunch, back extension, seated leg extension, seated leg curl and hip abduction). At each station, participants completed three sets of 8–15 repetitions with a load that corresponded to 50–80% of estimated 1 repetition maximum (RM). Progress in muscle strength was measured once a month and the loads for the following month were adjusted as appropriate. The training was supervised by an experienced trainer.

2.3. Muscle strength

Subjects' estimated 1-RM for leg press, leg curl, hip abduction, seated row, abdominal crunch, and total muscle strength were measured monthly and used as a primary outcome of this study. One RM for each exercise was estimated from 8-RM tests by applying Epley's formula [22]. Before the 8-RM tests women performed aerobic warm-up. Women were also clearly instructed that they should experience no pain and that they could stop the test at any point. Then women were introduced to the equipment and explained how to use it. With the equipment, they first performed 2–3 warm-up/practice sets with light resistance. After the women were familiarized with the machine the actual 8-RM test started. The aim was to achieve 8-RM optimally in 2–3 sets, but in maximum of 5 sets. After completing each set successfully, the load was increased if both the participant and the tester felt that she could complete 8-RM with heavier load. The training was performed with both pneumatic resistance and weight stack equipment. In pneumatic machines loads can be adjusted without steps, so small increases in predicted 1-RM were not a problem. In weight stack machines, the smallest allowed load adjustment varied between the 2.5–5 kg. If the 1-RM was close to a load that was available in the machine, then this was selected. If the 1-RM was in between of two available stack weights then the lower load was selected. Progress in muscle strength was measured once a month and the loads for the following month were adjusted as appropriate. Total muscle strength was calculated as a mean of leg press, leg curl, hip abduction, seated row, and abdominal crunch 1-RM values. In addition to absolute strength, a set of sensitivity analyses were performed, where muscle strength in relation to baseline body weight and lean body mass was investigated. Moreover, total relative change in muscle strength was also calculated ((4-month muscle strength – baseline muscle strength)/ baseline muscle strength × 100).

2.4. Physical functioning

Handgrip strength and maximum isometric knee extension were measured from the dominant side in an adjustable dynamometer chair (Good Strength, Metitur Ltd., Jyväskylä, Finland). The best result out of three trials was reported in kilograms.

Gait speed and endurance were measured with the 15-foot Walk Test (4.57 m) and the 6-Minute Walk Test, respectively. In the 15-foot Walk Test the time was measured with a standard stop watch and the result was the time taken to walk 15 feet with a walking start. In the 6-Minute Walk Test, the participant was informed to walk as fast as possible yet safely. The distance covered in 6 min was measured with 5 m accuracy. These tests were conducted indoors, the 6-Minute Walk Test was performed in a corridor where turning points were marked with cones, placed at 20 m distance from each other.

2.5. Body composition and anthropometrics

Body fat percentage, lean body mass, and weight were measured in light clothing before the intervention by bioelectrical impedance analysis (InBody 3.0 eight-polar tactile electrode system (Biospace Co. Ltd, Seoul, Korea). Height was measured to the nearest 0.1 cm. BMI was calculated by dividing weight (kg) with height in meters squared. Waist-to-hip ratio was calculated from the measured waist (midways between the iliac crest and lower rib margin) and hip (widest part of hip circumference) with measuring tape.