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The effects of obesity, age, and relative workload levels on handgrip endurance

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ABSTRACT

The purpose of the study was to examine obesity and age effects on handgrip endurance across a range of relative workload levels. Forty-five non-obese and obese younger and older females performed fatiguing handgrip exercises at 20, 40, 60, and 80% of relative handgrip strength. The younger obese group demonstrated ~7% greater strength, 32% shorter endurance times, and ~34% faster rate of strength loss, accompanied by heightened perception of effort, than the younger non-obese group. However, these obesity-related differences were not observed in the older age group. Moreover, there were no interactions between relative workload levels, obesity, and age on any of the fatigue measures. Findings obtained here suggest that work-rest schedules computed from existing force endurance prediction models may not be protective of the younger obese working population.

1. Introduction

With the increased prevalence of obesity (defined as having a body mass index (BMI) $\geq$30 kg/m^2), particularly in the U.S. workforce, the ergonomic consequences of obesity have gained increasing attention in the literature. Obesity is correlated with increased lost workdays from workplace injuries and other health conditions (Finkelstein et al., 2010; Østbye et al., 2007). In the most obese, those with BMI >40 kg/m^2, distal upper extremity injuries occur twice as often (Pollack et al., 2007). Changes in job demands, from added segment masses, and in worker capacities may alter risk of injury with obesity. In addition, there are implications for task performance and fatigue development, important workplace outcomes.

Obesity is associated with slower movement during manual handling and controlled hand-based tasks (Berrigan et al., 2006; Tetteh et al., 2009) (Berrigan et al., 2006; Tetteh et al., 2009) and poorer performance during handgrip and fine motor control tasks (D'Hondt et al., 2008; Mehta and Shortz, 2014). A growing number of studies have examined obesity-related changes in muscle strength (Cavuoto and Nussbaum, 2013b; Hulens et al., 2001; Maffiuletti et al., 2007), however little is known on its effect on endurance and fatigue. When performing sustained contractions, decreased capillary density and lower blood flow to the muscle, observed with obesity (Kern et al., 1999), may lead to a faster onset of muscle fatigue (Newcomer et al., 2001), which can result in decreased muscle capacity (Looze et al., 2009; Visser and Dieen, 2006).

Eksioglu (2011) reported an inverse relationship between BMI and endurance time during sustained isometric grip contractions at 30% of maximum strength. Similarly, trunk endurance was shown to be reduced during a modified Sørensen back endurance test (Fogelholm et al., 2006; Kankaanpää et al., 1998), although the results from the latter may have been affected by higher load levels caused by the additional body mass of obesity. For both of these studies, correlation between body mass and endurance was a secondary outcome, since neither was focused on determining obesity-related differences in fatigue resistance and only included a small sample of overweight and obese participants. This prior work was also limited to a single exertion level for each task. It is unclear to what extent fatigue resistance of the upper extremity is impaired in overweight and obese individuals, and whether this relationship is workload and muscle dependent.

In ergonomics practice, maximum holding time (endurance time) during a sustained isometric contraction is a commonly used measure for fatigue development. Dating back to the presentation of Rohmert's curve in 1960, it has been used to understand work demands and define work-rest schedules for the prevention of work-related injury (El ahrache & Imbeau, 2009; El ahrache et al., 2006; Frey Law and Avin, 2010; Gnaneswaran et al., 2013;

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Rohmert, 1962, 1973). Models of the relationship between the relative demand of the task and endurance time are used as an indicator of fatigue resistance and the rate of fatigue development (Dieen and Vrielink, 1994; Ma et al., 2009). Updated versions of the force-endurance model have been presented over the past 50 years, with data to account for differences by muscle and age group. For instance, aging has been shown to result in longer endurance times and increased fatigue resistance for static tasks (Avin and Frey Law, 2011). However, to date none of the studies have systematically considered individual differences based on level of both obesity and age across a range of workloads. Given that reduced capacity with obesity may result in shorter endurance times and faster fatigue development, and that these changes may vary with age, the purpose of this study is to evaluate the main and interactive effects of age and obesity on handgrip strength and endurance for multiple levels of relative workload. It was hypothesized that the interaction between age and obesity would impact fatigue development, particularly in the older obese group, and that this relationship would be workload-dependent.

2. Methods

2.1. Participants

The current study was conducted across two sites, using the same experimental protocols and equipment to avoid methodological and equipment-related discrepancies. Twenty six females from the local community in Buffalo, NY and twenty two females in College Station, TX were recruited from the local community into four groups: non–obese young (18.5 $\leq$ BMI < 25 kg/m^2, 20–35 years), non–obese older (18.5 $\leq$ BMI < 25 kg/m^2, >50 years), obese young (BMI >30 kg/m^2, 20–35 years), and obese older (BMI >30 kg/m^2, >50 years). Demographic characteristics of the study participants are shown in Table 1, pooled across both sites. Only females were recruited for this study to minimize gender-related variability in obesity characterization and muscle performance (i.e., strength and endurance). Exclusion criteria included any musculoskeletal disorders that would impair the ability to perform the experiments. In addition, the participants were not involved in high levels of aerobic or resistance training that may have affected their grip strength or endurance. Participants completed an informed consent procedure approved by the Institutional Review Boards of the University at Buffalo and Texas A&M University.

2.2. Procedures

Participants completed four experimental sessions that consisted of handgrip strength and endurance testing. At the start of the first session, demographic information, health history, and anthropometric measurements were taken. Participants performed a series of warm–up exercises with a stress ball for 2 min and were also provided practice with the grip dynamometer. After sufficient rest, a minimum of three maximum voluntary contractions (MVCs) were measured at the beginning of each session. Participants were seated upright with their upper arm at their side. A digital grip dynamometer (Hoggan microFET 4, Salt Lake City, UT, USA) was held in the dominant hand and the participant maintained a standardized grip testing posture with their elbow bent at 90° with the non–dominant arm resting on the lap (Fig. 1A). The maximum strength value obtained from the MVCs during the first session was used to determine the target load levels for each participant's endurance tasks.

Table 1
Demographic information of participants (mean (SD)).

Group	Younger non-obese	Younger obese	Older non-obese	Older obese
n	13	9	12	11
Age (years)	25.3 (5.2)	23.1 (4.0)	54.8 (5.4)	66.4 (13.1)
Height (cm)	162.4 (8.8)	160.9 (7.8)	162.9 (5.4)	161.6 (7.0)
Weight (kg)	59.1 (10.0)	86.1 (14.7)	62.0 (8.9)	94.3 (22.0)
BMI (kg/m^2)	22.2 (2.2)	33.1 (3.6)	23.3 (2.9)	36.1 (8.1)

Following strength measurement and sufficient rest, handgrip endurance was assessed. Target relative loads of 20, 40, 60, or 80% MVC were used to cover the range of possible exertion levels observed in the workplace and to facilitate comparison with previous endurance data (Rohmert, 1962). Participants completed the endurance task at one target load per session. The presentation order of the tasks was randomized within each group and sessions were separated by at least 48 h each. Participants were instructed to maintain the target workload for as long as they were able and were provided real–time visual feedback of their generated force against their target force (Fig. 1B). Every 30 s during the task, participants were asked to provide ratings of perceived exertion (RPE) using the modified Borg CR-10 scale, where the scale ranged from 0 "*Nothing at all*" to 10 "*Extremely strong, almost maximum*". The endurance task ended when either the participant indicated she could no longer continue or her exerted force dropped >10% below the required effort level for more than 5 s. Immediately following the endurance task, participants completed a post-task MVC. In general strength loss (calculated as percent MVC decrease from initial MVC) provides a direct measure of localized muscle fatigue (Vøllestad, 1997) to evaluate if tasks are fatiguing. However the tasks in the present study were intended to induce fatigue, thus strength loss was expected to remain comparable between groups. Therefore, rate of strength loss, calculated as the ratio of strength loss to endurance time, was employed to assess age- and obesity-specific differences in the progression of fatigue development. Similarly, RPE rate was calculated as the ratio of maximum RPE to endurance time.

2.3. Statistical analysis

Separate mixed-factor analyses of variance (ANOVAs) were used to assess the main and interactive effects of obesity level (non-obese or obese), age (young or older), and workload (20, 40, 60, or 80% MVC) on endurance time, rate of strength loss, and RPE rates. Parametric model assumptions were assessed and log transformations of endurance time, rate of strength loss, and RPE rates were used to achieve homoscedasticity. Relationships between endurance time and workload were analyzed using non-linear regression based on visual inspection of the data. Power functions, in the form of Time = $b_0(\%MVC/100)^{b_1}$ were fit for each individual (Frey Law and Avin, 2010). Separate ANOVAs were used to examine obesity and age differences in the derived model

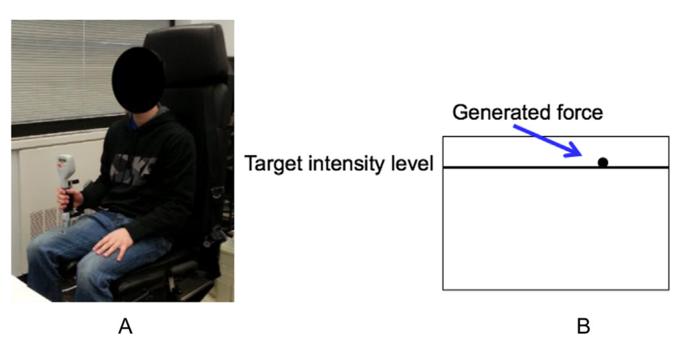

Fig. 1. (A) Posture adopted during submaximal handgrip exercises and (B) real-time feedback provided to the participants.