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Differences in functional performance of the shoulder musculature with obesity and aging

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ABSTRACT

The workforce includes an increasing number of workers who are obese and/or older, which may lead to higher rates of workplace injuries. We examined the main and interactive effects of obesity and age on strength and functional performance during sustained isometric exertions involving shoulder flexion in two postures. Four groups of eight participants each (non-obese ($18.5 < \text{BMI} < 25$ kg/m^2) young (18–25 years), non-obese older (50–65 years), obese ($30 < \text{BMI} < 40$ kg/m^2) young, and obese older) completed static endurance tasks in each posture, at fixed target levels of shoulder moment. Shoulder strength was ~25% higher with obesity and equivalent between age groups. Both obesity and age affected endurance time, with the obese and younger groups both having shorter endurance. Obesity and age did not have an interactive effect on endurance time and the results were inconclusive regarding acute fatigue effects for individuals who are older and obese. Further work is needed under more realistic task conditions, to explore the likely complex effects of these individual differences.

Relevance to industry: Shoulder strength was increased with obesity, though obesity was associated with substantially reduced endurance times. Such a difference may have implications for determining work-rest schedules based on task demand and predicted endurance times. It remains unclear whether obesity and age interact to cause substantial functional decrements.

1. Introduction

Work-related musculoskeletal disorders (WMSDs) represent a serious challenge in the workplace due to their associated economic burden and adverse effects on workers' quality of life. Overexertion injuries are among the leading types of WMSDs (Anderson and Budnick, 2009), and for cases requiring days away from work, shoulder and wrist injuries result in the most lost work time (BLS, 2010). Two important contemporary trends in workforce demographics may be associated with an increase in the future incidence and cost of these workplace injuries: the increasing prevalence of obesity (Flegal et al., 2010) and the aging of the workforce (BLS, 2008).

The prevalence of obesity worldwide has nearly doubled over the past 30 years (WHO, 2011) and almost 1.5 billion adults and 85% of hourly manufacturing workers are either overweight or obese (Finucane et al., 2011; Pollack et al., 2007), defined as having a body mass index (BMI = kg/m^2) of 25–30 or >30, respectively. Those with class I or II obesity ($30 < \text{BMI} < 40$ kg/m^2) have higher musculoskeletal injury rates than those with BMI < 25 kg/m^2 (Odds Ratio = 1.54; Pollack et al., 2007). Individuals who are obese are over 60% more likely to be absent from work than those who are not obese, and obesity-related work absence costs employers an estimated $4 billion each year in the US (Cawley et al., 2007). With the added physical demands imposed by obesity, there may be implications for worker fatigue development, which can ultimately affect performance and the risk of injury. For example, additional mechanical requirements from upper extremity masses can lead to increased arm movement times during the performance of rapid tasks (Berrigan et al., 2006). With a longer task duration, the upper extremity muscles must support a heavier arm for more time.

Few studies, however, have considered the relationship between obesity and endurance. For a sustained hand grip task at 30% of maximal capacity, a fairly strong inverse association ($r \sim -0.6$) was found between BMI and endurance time (Eksioglu, 2011). Similarly, reduced endurance with higher BMI has also been reported for static trunk extension tasks in a prone position requiring support of the entire upper body mass (Fogelholm et al., 2006; Kankaanpää et al., 1998). The hand grip task required minimal

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body mass support, compared to the more substantial support required for the trunk extension tasks. Common occupational tasks using the upper arm and shoulder likely necessitate body mass support in between these two levels. It is also reasonable to expect a different endurance response with obesity for the upper extremity, since the relative lack of weight bearing in contrast to the lower extremity will alter the typical chronic training effects that are thought to occur with increased body mass (Lafortuna et al., 2005). In our earlier study of obesity-related differences in strength and endurance during sustained isometric exertions (Cavuoto and Nussbaum, 2013), we found higher levels of shoulder strength in individuals who are obese, but did not see any differences in endurance time for a prolonged static task at a fixed level of task demand. However, this earlier work considered only a single posture and only young participants.

Aging is also of particular interest, since over the past 30 years there has been a doubling of the number of workers aged 65 and older (BLS, 2008). The Bureau of Labor Statistics (2009) projected this trend to continue, estimating that workers over 55 will account for 25% of the worker population by 2018 (compared to 18% currently). With this increased number of older workers, the prevalence of severe workplace injuries will likely increase since the median lost workdays per injury increases with age (BLS, 2010). When considering aging alone, there are significant changes to muscle physiology that also affect muscular capacity. Older adults lose their force-generating ability, as evidenced by strength reductions (Frontera et al., 2008) that result in part from slower contractile properties and loss/shrinkage of fibers (Thompson, 2009).

Addressing the increased prevalence of individuals who are older and obese, some recent research has focused on potential interactive effects of obesity and aging on musculoskeletal and functional changes. There are conflicting findings of increased (Rolland et al., 2004) as well as similar (Miyatake et al., 2000) absolute strength with older age and obesity, perhaps a result of diverging influences of age-related decreases and obesity-related increases in muscle strength. In addition, older individuals who are obese have higher rates of reported limitations in movement and performance of daily activities than those who are non-obese (Alley and Chang, 2007). Tests of walking, stair climbing, flexibility, and balance, in conjunction with self-reports, have confirmed that there is both a performance decline and an increased risk of mobility limitation in individuals who are older and obese (Houston et al., 2007, 2009; Larsson and Mattsson, 2001; Zoico et al., 2004). One longitudinal survey of workers found the combination of age >40 and BMI >30 kg/m^2 to have the strongest association with upper extremity tendonitis (Werner et al., 2005). While this evidence points toward functional consequences, most prior research has concentrated on basic activities of daily living, and therefore the overall ergonomics relevance may be limited.

Although the health and performance consequences of obesity and aging have gained increasing attention in the literature, there are still major limitations regarding potential effects on work-related functional performance. Here, we define functional performance as encompassing endurance and acute fatigue effects (particularly regarding discomfort and motor control). Functional performance is an important consideration for the design of tools, workstations, and work tasks; however, the impacts of obesity and age on functional performance have only received minimal attention in the literature. The purpose of this study was to assess whether age and obesity have interactive effects on shoulder capacity for prolonged static tasks. Two specific tasks were used, involving two postures differing in the extent to which support of upper extremity body mass was needed. It was hypothesized that: 1) there would be interactive effects of obesity and age on shoulder strength; 2) there would be decreased functional performance for individuals who are obese; 3) this effect on functional performance would be more substantial with older age; and 4) the effect of obesity on functional performance would be larger when there was a greater need for supporting body segment mass.

2. Methods

2.1. Participants

Thirty-two right-hand dominant participants (aged 18-25 and 50–65 years) completed the study, and were recruited from the university and local community to form four groups, gender balanced in each: non-obese ($18.5 < \text{BMI} < 25$ kg/m^2) young, obese ($30 < \text{BMI} < 40$ kg/m^2) young, non-obese older, and obese older. These age ranges were intended to capture individuals at the typical start and end of working life, and the BMI range for the obese group was used to avoid the effects of likely co-morbidities present at higher levels. The younger participants were university students and the older participants were either retired or employed in non-physically demanding jobs, such as office work. Participants completed an informed consent procedure approved by the Virginia Tech Institutional Review Board. Physical activity levels of the participants were assessed using the Global Physical Activity Questionnaire (Armstrong and Bull, 2006). Participants were stature-matched at group levels within age and obesity groups and had comparable levels of physical activity (summary data on the four groups are provided in Table 1). Waist and hip circumference values support that BMI differences were due to obesity and not another factor such as high muscularity (Duvigneaud et al., 2008; National Institutes of Health (NIH) et al., 2000; Zhu et al., 2004).

2.2. Procedures

Participants completed two experimental sessions on different days, separated by at least two days to minimize any effects from residual fatigue or muscle soreness. Each experimental session involved strength testing and an isometric shoulder endurance task

Table 1
Summary data from the four participant groups (mean (SD)) and results of ANOVA for main effects of obesity and age.

Measure	Group ($n = 8$ in each group)				Obesity p-value	Age p-value
	Non-obese young	Obese young	Non-obese older	Obese older		
Age (yr)	20.8(2.5)	22.3(2.1)	57.0(5.0)	54.4(2.8)	0.63	$<0.001^*$
Body mass (kg)	69.0(6.1)	101.3(12.2)	75.0(5.9)	106.8(17.7)	$<0.001^*$	0.17
Stature (m)	1.74(0.1)	1.72(0.1)	1.75(0.1)	1.71(0.1)	0.30	0.91
BMI (kg/m^2)	22.7(1.8)	34.1(2.8)	24.4(0.9)	36.4(3.3)	$<0.001^*$	0.03^*
Waist circumference (cm)	82.5(5.7)	108.2(7.0)	89.5(5.0)	119.8(12.8)	$<0.001^*$	0.003^*
Hip circumference (cm)	94.8(4.9)	117.7(8.7)	103.1(4.6)	123.8(5.7)	$<0.001^*$	0.002^*
Waist-to-hip ratio	0.87(0.1)	0.92(0.1)	0.87(0.1)	0.97(0.1)	0.005^*	0.37
Physical activity (MET-min/wk)	1250(1220)	1070(1030)	1460(910)	1250(1210)	0.62	0.62

$^*p < 0.05$ for main effects of obesity and age.

in one of two postures (shown in Fig. 1). These postures were intended to roughly simulate an individual holding an object (e.g., tool) in front of the body vs. supporting it overhead, and with the former involving a more substantial need to support segmental upper extremity masses. In the first posture (Fig. 1a), the participant's arm was kept parallel to the ground and with the elbow extended. In the second posture (Fig. 1b), the shoulder was flexed 135°, with an included elbow angle of 90°, so that the lower arm was at 45° from vertical. In the following, "extended" and "flexed" denote the respective postures, based on the relative orientations of both the shoulder and elbow. For both postures, participants held their wrist in a neutral posture and their hand in a relaxed fist. Segment orientations were measured/monitored using an inclinometer, and the presentation order of the postures was counterbalanced.

At the start of each session, participants completed an initial warm-up period that involved a set of 10 each of brief, intermittent static and dynamic shoulder flexion exertions with and without a 1 kg handheld mass. Following the warm-up period, participants performed a series of isometric maximum voluntary contractions (MVCs), involving shoulder flexion in the posture being tested in a given session (see Fig. 2 for illustration of experimental protocol). MVCs were completed using a commercial dynamometer (Biodex System 3 Pro, Biodex Medical Systems, Shirley, NY). During these, the participant's upper body and waist were secured, their feet were supported by a footrest, and the dynamometer center-of-rotation was aligned with the glenohumeral joint. Participants were asked to progressively build to a maximum exertion, hold it, and then ramp down to rest, while maintaining the test posture and pressing their upper arm against a padded fixture. Over the five seconds of each MVC, participants were given verbal encouragement and visual feedback of their moment output. At least three MVC trials were completed, each separated by two minutes of rest, until peak moments were non-increasing. Moment data were sampled at 1024 Hz and hardware low-pass filtered with a 15 Hz cutoff frequency. Corrections were made for gravitational effects on the dynamometer fixture and body segments, and the maximum moment across MVC trials was recorded as the participant's MVC.

After strength testing, participants rested for 2–5 min, until they felt no discomfort in their shoulder, and then completed an endurance task in one of the two shoulder postures. The task involved isometrically generating an absolute moment of 9 Nm above that needed to support arm mass, and moments were recorded continuously with the same methods as those for MVCs. This fixed external load was used to represent the approximate external moment at the shoulder for a 50th percentile male holding a 1.5 kg object in the posture shown in Fig. 1a. A computer monitor displayed the generated and target moments throughout the task, and participants were instructed to maintain the generated moment as close to the target as possible for as long as possible. The task continued until the participant indicated they wanted to stop or they could no longer track the target, dropping >20% below the target without re-attaining it (Bazzucchi et al., 2005; Eksioglu, 2011).

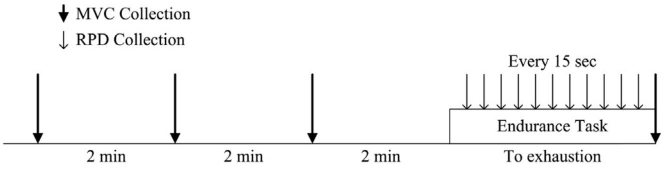

Fig. 2. Timeline of experimental procedures during a single session.

During the endurance tasks, participants provided ratings of perceived discomfort (RPDs) for the shoulder at 15-s intervals, using a 10-point scale (Borg, 1990) that was visible to them throughout the task. Strength loss was quantified by a post-task MVC in the relevant posture performed right after the end of the endurance task.

2.3. Dependent measures and analysis

Pre-fatigue absolute strength (MVC), relative strength (MVC/body mass), and endurance time were obtained in each of the two shoulder postures. Rates of change in strength, moment fluctuations, and RPDs were calculated from data collected during the endurance tasks to assess fatigue-related effects. The rate of strength loss was determined as the percentage change in MVC divided by the endurance time. To quantify moment fluctuations, the data were first separated into consecutive, non-overlapping 5 s windows throughout each endurance task. Then, the coefficient of variation for each window was obtained as the standard deviation of the generated moment divided by the mean (Tracy et al., 2005). Linear regression (vs. time) was used to obtain rates of changes in fluctuations (across the windows) and RPDs (at every 15 s). In addition, the final rating given prior to the endurance time was recorded as the maximum RPD.

Separate mixed-factor analyses of variance (ANOVAs) were used to assess the main and interactive effects of obesity, age, and task on each dependent measure. Presentation order was included as a blocking variable and absolute strength was included as a covariate when assessing endurance and the acute fatigue effects. Due to the exploratory nature of this study, and in particular the small sample size in each group, which was limited by available resources, the


(a) (b)

Fig. 1. Arm postures used for strength testing and endurance tasks: (a) extended posture and (b) flexed posture. Note that participants needed to be semi-reclined so that the dynamometer axis of rotation could be aligned with that of the shoulder.

level of significance for all analyses was set at $p < 0.1$. For a similar reason, gender differences were not assessed, though these were accounted for, in part, using the noted covariate. For one participant (male, young, obese), endurance and fatigue-related results from the flexed task were discarded as clear outliers using the generalized extreme Studentized deviate test (Kutner et al., 2005). Endurance times and rates of RPD increase were log transformed to achieve homoscedasticity. All summary data are presented as means (95% confidence intervals), with the data back-transformed to the original units as needed. Simple effects tests were used to explore significant interaction effects. Associations between the rates of strength loss and RPD increase were assessed using coefficients of correlation (ρ) from bivariate correlations, obtained separately for each of the four participant groups.

3. Results

The obese group overall had ~25% higher absolute strength ($F_{(1,28)} = 4.56$; $p = 0.042$; $\eta^2 = 0.13$; Fig. 3). There was not a significant effect of age on absolute strength ($p = 0.80$) or an obesity × age interaction ($p = 0.71$). The obese group had ~14% lower relative strength ($F_{(1,28)} = 3.57$; $p = 0.0692$; $\eta^2 = 0.10$; Fig. 3) across both postures. No significant obesity × task interaction was observed for either absolute or relative strength ($p = 0.71$ and $p = 0.78$, respectively).

There was a main effect of obesity on endurance time ($F_{(1,28)} = 23.9$; $p < 0.0001$; $\eta^2 = 0.023$), with the non-obese group having ~18% longer endurance time (166 (143–193) s) than the obese group (138 (115–167) s). There was also a main effect of age ($F_{(1,28)} = 4.11$; $p = 0.0526$; $\eta^2 = 0.034$). The older group (169 (143–201) s) had ~24% longer endurance than the younger group (136 (115–160) s). Fig. 4 summarizes the endurance times by obesity group, age group, and task.

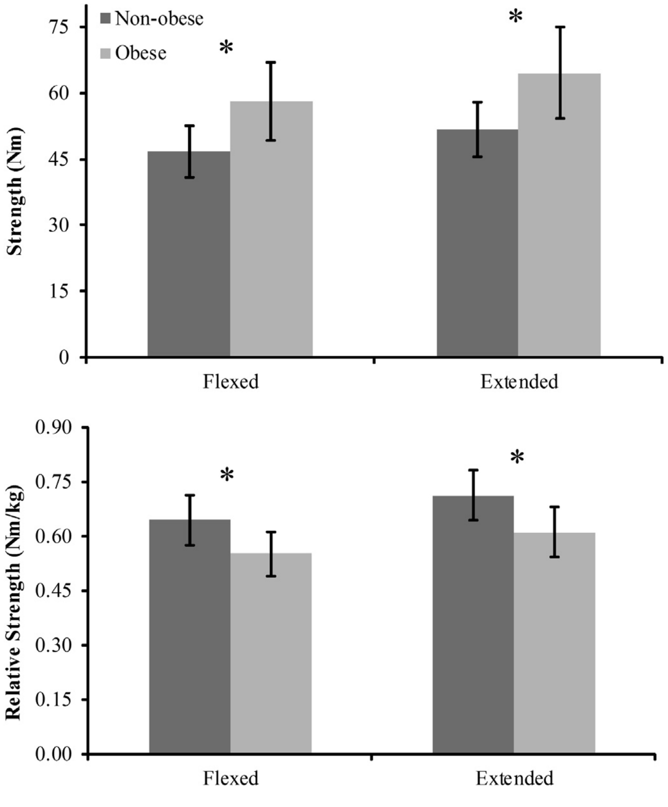

Fig. 3. Mean absolute (top) and relative (bottom) strengths for both obesity groups and tasks. Error bars represent 95% confidence intervals, and the symbol * indicates a significant ($p < 0.1$) difference between the non-obese and obese groups within each task.

The rate of strength loss was significantly affected by obesity ($F_{(1,27)} = 9.40$; $p = 0.0049$; $\eta^2 = 0.00055$), though there was not a main effect of age ($p = 0.26$). There was also a significant obesity × age interaction ($F_{(1,27)} = 4.23$; $p = 0.049$; $\eta^2 = 0.023$) where lower rates of strength loss were observed for the non-obese older group compared to the obese older group (Fig. 5). Rates of increase in moment fluctuation were consistent across the four groups ($p > 0.20$) with an overall mean of 1.3×10^{-4} ($9.8 \times 10^{-5} - 2.3 \times 10^{-4}$)/s. Obesity also had an effect on the rate of RPD increase ($F_{(1,27)} = 8.13$; $p = 0.0082$; $\eta^2 = 0.006$) and there was a significant ($F_{(1,27)} = 10.8$; $p = 0.0028$; $\eta^2 = 0.12$) effect of age. Specifically, the obese group had ~16% higher rates than the non-obese group (0.074 (0.054–0.078) vs. 0.064 (0.048–0.069) s^{-1}) and the younger group had ~48% higher rates than the older group (0.074 (0.063–0.088) vs. 0.050 (0.042–0.061) s^{-1}). Maximum RPD was significantly ($F_{(1,25)} = 5.30$; $p = 0.030$; $\eta^2 = 0.16$) lower for the older group (8.8 (8.2–9.4)) compared to the younger group (9.7 (9.5–9.9)). Correlations (ρ) between the rates of strength loss and RPD increase were comparable within each of the four obesity/age groups (ranging from 0.64 to 0.72).

4. Discussion

4.1. Effects of obesity and age on strength

We observed ~25% higher absolute and ~14% lower relative shoulder strength for the obese group, consistent with our earlier study (Cavuoto and Nussbaum, 2013) wherein an obese group had ~24% higher absolute and ~20% lower relative shoulder flexion strength. The absolute strength findings are also consistent with previous evidence of a positive correlation between body mass and isometric shoulder flexion and abduction strength (Lannersten et al., 1993). However, the current results conflict with a separate study that found no obesity-related differences in upper limb strength for muscles (*triceps brachii* and pectorals) not regularly involved in body mass support (Lafortuna et al., 2005). Although strength differed with obesity, there was no main effect of age or interactive effects of obesity and age on muscle strength. Therefore, our first hypothesis of an interactive effect between obesity and age on strength was not supported. This absence of age-related differences conflicts with previous reports of an age-related strength decline and specific findings for the shoulder that suggest 10–20% reductions in isometric shoulder strength among similar-aged participants (Hughes et al., 1999; Yassierli et al., 2007). However, the current results are consistent with those from Lannersten et al. (1993), who found no difference in shoulder flexion strength

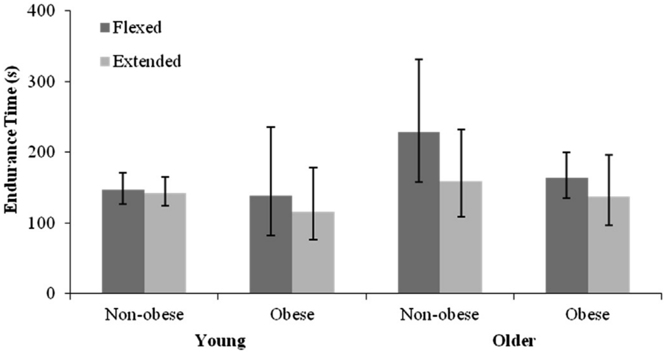

Fig. 4. Mean endurance times with respect to age group, obesity group, and task. Error bars represent 95% confidence intervals.

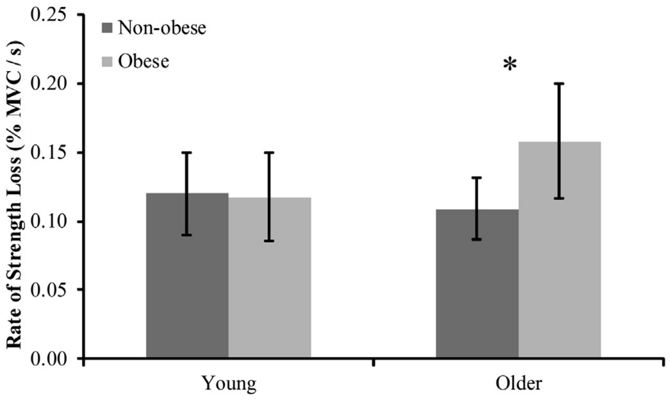

Fig. 5. Mean rates of strength loss with respect to age and obesity group. Error bars represent 95% confidence intervals. The symbol * indicates a significant ($p < 0.1$) difference between the non-obese and obese groups within each age group.

between older and younger females, although they did report that older males had 89% of the shoulder flexion strength of younger males. Individual variation between the study samples and the specific shoulder postures used may partially explain these differences. For example, Hughes et al. (1999) kept the elbow at 90° for all tests of shoulder strength; elbow posture affects the external moment at the shoulder during flexion and may have affected moment generating ability. Lannersten et al. (1993) used a similar posture to the current “extended” posture (Fig. 1a) for determining shoulder flexion strength. Further, neither study reported matching their groups based on stature or physical activity level, two factors that are positively correlated with strength (Lannersten et al., 1993; Neder et al., 1999).

4.2. Functional performance with obesity

Based on previous evidence suggesting functional impairments with obesity, we hypothesized that there would be decreased functional performance among individuals who are obese, as measured by endurance time, motor control (moment fluctuations), and discomfort. The non-obese group had ~18% longer endurance time, supporting this hypothesis, and is consistent with a previous study of grip endurance for males that found a negative correlation between BMI and endurance time when exerting at 30% MVC (Eksioglu, 2011). In the current study, we used fixed, absolute load levels for the endurance task. Based on the observed differences in strength, the task was thus performed at a different relative demand for each participant. Specifically, exertions for the obese group were approximately 5% MVC lower than for the non-obese group.

Traditionally, relative load and maximum holding time are related following an exponential model, with decreased endurance at higher levels of relative load (e.g., Garg et al., 2002; Mathiassen and Åhsberg, 1999). Anticipated obesity-related differences in endurance time can be predicted from the mean relative demands and using exponential parameters determined for the shoulder by Frey Law and Avin (2010), and from this, the lower relative demand for the obese group should have resulted in ~20% longer endurance time. That the obese group did not have a longer endurance time may suggest impaired functional performance in this group. Consistent with this, the obese group had higher rates of strength loss and RPD increase during the endurance task. In contrast, and opposing the hypothesis, rates of moment fluctuation increase were equivalent between the obese and non-obese groups. An absence of obesity-related differences in this measure was also observed in our earlier study of sustained shoulder flexion endurance within a younger population (Cavuoto and Nussbaum, 2013). It is thus possible that some of the measures used and/or the current sample size may not have been sensitive enough to detect obesity-related neuromuscular differences. There is also substantial intra- and inter-individual variability of endurance and fatigue measures (e.g., Clark et al., 2007; Hinckson and Hopkins, 2005).

4.3. Interactive effect of obesity and age on functional performance

We also hypothesized that the decrease in functional performance for individuals who are obese would be more substantial with older age. We did find several effects related to age, specifically that the older group had longer endurance than the younger group. Further, higher rates of RPD increase were observed for the younger group, consistent with their shorter endurance times and higher maximum RPDs. Age-related increases in endurance time have been reported for sustained exertion tasks at a fixed relative load (Avin and Frey Law, 2011; Bazzucchi et al., 2005; Yassierli et al., 2007). With aging, a reduction in fatigable (Type II) muscle fibers has been hypothesized to result in longer endurance times (Klein et al., 2003; Yassierli et al., 2007). In the current study, the fixed absolute load was approximately 30% MVC for both age groups, and the main effect of age is consistent with these previous findings that found ~20% longer endurance times for older adults compared to younger at a similar relative load (Yassierli et al., 2007). However, there was inconclusive evidence found here to support the hypothesized interactive effect of obesity and age, in that the endurance time differences between the obese vs. non-obese participants were relatively consistent between age groups. However, the older obese group had a significantly higher rate of strength loss than the non-obese group, while there was no difference between the young groups.

To the authors' knowledge, this is the first study to examine an interactive effect of age and obesity on muscle endurance and the related acute fatigue effects, and conflicting outcomes may have resulted from the small size and the large variability of measures noted above. Further, differences in motivation both between sessions and between participants and groups may have affected the endurance times. For example, results showing a main effect of age on maximum RPD may indicate that the younger participants were working “harder”. However, correlations between the rates of strength loss and RPD increase were consistent across all groups. This implies that participants had similar abilities to assess their fatigue development, however it does not eliminate the possible influence of motivation.

4.4. Interactive effect of task and obesity on functional performance

Our final hypothesis was that the effect of obesity on functional performance would be dependent on the need for support of body segment mass. Specifically, a larger effect of obesity was expected in the extended vs. flexed postures due to the larger external shoulder moments generated in the former. However, this hypothesis cannot be accepted based on the conflicting task-related differences found. Although only two postures were tested, the lack of an obesity × task interaction for shoulder flexion strength suggests that obesity-related differences are consistent across postures for a given joint. In addition, among the obese groups, endurance time in the flexed posture was consistently ~30% longer than for the extended posture for both the young and older participants (Fig. 4). For the non-obese groups, only a minor difference in between-task endurance time was observed for the young group, while a much more substantial difference was seen for the older group.

Anticipated differences in endurance time related to posture can be predicted using the same approach described earlier (Section 4.2). For both the obese and non-obese groups, the relative demand in the flexed posture was approximately 5% MVC lower than for the extended posture (24 vs. 29 and 29 vs. 34% MVC, respectively). This leads to a predicted shortening of endurance time for the extended posture of ∼28%, which is comparable to the results in the obese groups. The non-obese groups, however, did not follow such a prediction. Further inspection of the data revealed that two participants in the non-obese older group had endurance times in flexed posture trials that were relatively long, and that these times were somewhat inconsistent with the respective extended posture trials for the specific participants as well as relative to other participants in this group. Given the small sample, these few data points were likely influential, and may have been due to differences in motivation and/or familiarization between sessions.

4.5. *Limitations*

Limitations related to sample size and dependent measures were noted earlier. An additional limitation of this study is the inclusion of only two levels of obesity and only individuals with BMI <40 kg/m^2, though only ∼6% of the population has BMI >40 kg/m^2 (Flegal et al., 2010). Further, only two age groups were considered. Similar to the use of only two obesity groupings, the middle age of the population was not included to achieve a separation between the tested groups and thereby to improve the ability to detect age-related differences and obesity × age interaction effects. Generalization of the present results may be limited, specifically to other muscle groups, postures, and tasks than those examined here.

5. Conclusions

Higher strength was found among individuals who are obese, consistent with previous findings, though previously reported strength declines with age were not observed. Both obesity and age had effects on endurance time, with the obese group having shorter endurance and the older group having longer endurance. Some evidence was found for an obesity × age interactive effect on endurance time, although the results did not provide a conclusive indication of functional performance impairment for individuals who are older and obese. In addition, while participants had a longer endurance for the flexed vs. extended postures, as expected, inconsistent group-level differences were seen for the interaction between obesity and task. The effects observed here may differ for more complex tasks that involve movement and/or allow for recovery, since such tasks involve reported limitations in movement ability with older age and obesity. Further work is needed under more realistic task conditions to explore the likely complex effects of these individual differences.

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