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Low mean level sustained and intermittent grip exertions: Influence of age on fatigue and recovery

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The goal of this study was to quantify localised muscle fatigue resulting from low mean levels of exertion in younger (540 years) and older (550 years) adults. Fatigue, elicited in the finger flexor muscles by intermittent (10% mean maximum voluntary contraction (MVC)) and sustained (8% MVC) handgrip exercises, was quantified by a muscle twitch force response before, immediately after and during 3 h following exercise. Despite greater mean loads, recovery time was shorter following intermittent than sustained contractions, which suggests that recovery from fatigue is more sensitive to rest within the work cycle than mean work. The more pronounced effects for younger than older individuals following the sustained exertion indicate that changes in muscle fibre type composition might predispose older individuals to be more resistant to fatigue resulting from sustained contractions of low level. Performing hand exertion tasks requiring low mean force levels contributes to similar long-lasting fatigue effects regardless of gender and age. Intermittent periods of complete rest reduce muscle fatigue. Since fatigue was not perceived during recovery from the tested sustained and intermittent contractions, subjective evaluations may not be a reliable indicator of localised muscle fatigue.

Keywords: fatigue of long duration; muscle work cycle; ageing; hand grip exertion

1. Introduction

Localised muscle fatigue is an omnipresent response that may even result from low levels of sustained or intermittent muscle exertion (Sogaard et al. 1998, Taylor et al. 2000, Adamo et al. 2002). The type of fatigue associated with these activities can be evidenced by the relative decline in the muscle’s response to low (<20 Hz) vs. high (>50 Hz) frequency electrical stimulation (Edwards et al. 1977, Jones 1996), which has been named low frequency fatigue. In addition, this fatigue can be measured via changes in the twitch force response of the muscle to very low (2 Hz) frequency stimulation (Adamo et al. 2002) or changes in the power spectra of electromyograms and mechanomyograms of low force sustained muscle activities (Sogaard et al. 2003). Several studies have proposed that when fatigue persists for prolonged periods of time, on the order of several hours to days, a progressive accumulation of fatigue may ultimately lead to and predispose individuals to tissue disorders (Edwards et al. 1977, Green et al. 1984, Vollenst and Sejersted 1988, Bongiovanni and Hagbarth 1990, Martin and Armstrong 1995). Using this time recovery criterion and a constant tension-time product (TTP) ‘k’, studies have recommended upper limit mean contraction intensities of 10% maximum voluntary contraction (MVC) and 17% MVC for sustained and intermittent hand-grip exertions respectively (Bystrom and Kilbom 1990, Bystrom and Fransson-Hall 1994). Nevertheless, these upper limits may be too high. In a previous study, the recovery of muscle twitch force (MTF) fatigue induced by a 5% MVC isometric hand-grip exertion sustained for 30 min was not complete after 2 h rest (Adamo et al. 2002).

The subjects were comfortably seated in an upright posture, the right forearm resting in full supination on an adjustable table supporting the twitch force measuring apparatus (Figure 1). A metal plate placed over the hypothenar eminence stabilised the supinated forearm posture in relaxed position, so that no voluntary effort was required from the participant to maintain the forearm posture. Twitch forces, in response to submaximal electrical stimulation of the long finger (digit 3) flexor digitorum superficialis (FDS) muscle, were measured by a load cell attached to an adjustable system designed to accommodate anthropometric variations between participants. As shown in Figure 1, the load cell was placed perpendicular to the palmar surface midpoint between the distal and proximal interphalangeal joints of the long finger. To ensure precise repositioning of the finger across measurements, a rigid female receptacle was attached to the load cell and conformed to a small nipple placed on the finger phalanx. The adjacent digits were stabilised under Velcro strapping. The resolution of the load cell was 0.05 N (10 N max force) and the force signal was sampled at 1000 Hz.

The optimal location of the stimulation electrode (8 mm, Ag/AgCl) was determined by finding the region on the forearm where the maximum twitch force induced in the FDS could be recorded with no sensitivity to small changes in the location of the electrode. This location was clearly marked, thus allowing identical placement of the stimulation electrode for subsequent testing. In order to recruit a maximum number of motor units (MUs), it was important to stimulate the muscle at the highest tolerated intensity. To determine the corresponding level for each participant, individuals indicated when the level of 2 Hz stimulation became uncomfortable. The stimulus intensity was then adjusted to a level reported tolerable for a stimulation period of 2–3 min that corresponded to the lag time necessary to reach the steady state of MTF after potentiation (Desmedt and Hainaut 1968, Rankin et al. 1988) followed by data collection. For each participant, the same stimulation intensity was used for all tests. Overall, across participants, the stimulation intensity used to elicit individual muscle twitches ranged from 30 to 40 mA for the selected pulse duration of 0.1 ms. This, in turn, corresponded to finger twitch forces in the range of 0.10–0.15 N. Therefore, baseline finger twitch forces were of the same order of magnitude for all participants. The electrical pulses were delivered at a frequency of 2 Hz through a Grass medical stimulator (GS880; Grass Instruments) connected to an isolation unit (SIU5; Grass Instruments) and a constant current unit (CCU1A; Grass Instruments). An 18 mm pre-gelled Ag/AgCl ground electrode was placed over the right lateral epicondyle.
2.3. Work tasks

Participants were seated in an upright posture and performed the work task with their dominant hand. The upper arm was abducted approximately 20°, the elbow flexed at 120° and the forearm set at 0° pronation. Participants grasped a vertical handle split into a fixed and mobile part (Figure 2), which was adjusted to match individual hand-grip anthropometry. The mobile section, held with the digits II–V, was connected to the shaft of a pneumatic cylinder equipped with a load cell (Figure 2). The pressure in the cylinder, controlled by an electromagnetic valve driven by a waveform generator, was used to pull the mobile part of the handle and thus required a resistive grip force. This force, measured by the load cell, was displayed on a digital voltmeter placed in front of the participants at eye level. The duty cycle and pressure of the cylinder were adjusted to obtain ‘required’ grip force profiles corresponding to specific exercise regimens, as described by the experimental conditions below. The subject was instructed to exert the grip that was necessary to resist the pulling force applied to the handle. By design, the pull force remained constant regardless of the finger flexion angle.

Three work tasks, designed to have TTPs (k) ranging between 120 and 150, were tested, as described in Table 1. The task durations, contraction levels and duty cycles were selected to represent real work activities, recruit different proportions of type I and type II muscle fibres and be comparable to conditions in a previous study (Bystrom and Fransson-Hall 1994). The work tasks included a sustained contraction at 8% MVC for 15 min (S8), and two intermittent work tasks. One intermittent work task was 8.8 min in duration with contraction at 20%MVC for 6 s and relaxation at 0% MVC for 1.1 s (I20). The other intermittent work task was 8.8 min in duration with contraction at 70%MVC for 1 s and relaxation at 0% MVC for 3.1 s (I70). In addition, a smaller group of 12 subjects (six young and six old) were tested in a control condition (CR) corresponding to rest only, during which the participants remained seated without exerting the muscles of their hand placed initially in a neutral posture but free to be changed to avoid a static constraint.

The total work task durations were set to obtain TTPs of 120 and 150 for sustained and intermittent exertions, respectively. These parameters were selected to compare conditions with previous studies (Bystrom and Fransson-Hall 1994), to represent real work activities and to solicit small and large proportions of high threshold fast fatigable muscle fibres.

2.4. Subjective evaluation of muscle fatigue

Subjective perception of localised muscle fatigue in the dominant hand and forearm was rated (fatigue rating (FR)) on a ‘rating scale’ by placing a mark next to the
number corresponding to the verbal descriptor that most closely matched their level of perception (Figure 3). The scale was adapted from commonly used visual analogue scales (Lee et al. 1991) and included a number of verbal anchors compatible with human information processing (Miller 1956).

2.4.1. Procedure

All subjects were instructed to minimise physical exertions 24 h prior to the experiment. Activities such as lengthy computer use as well as tasks requiring a high level of physical exertion were strongly discouraged. On the first experimental day, the subjects were introduced to the experimental protocol, electrical stimulation procedures (as described above) and signed the consent forms. Then, the hand grip MVC was measured in the work task posture prior to the first experimental condition. Two MVCs approximately 5 s in duration and separated by a 3-min rest period were performed. Each MVC consisted of a 1–2 s force build up and a 2–3 s maximum exertion. The highest grip force level was used as the 100%MVC reference for all experimental conditions. All subjects were exposed to one of the three randomly assigned work tasks presented on non-consecutive days and a subgroup was tested in the control condition on a fourth day. For each experimental day, the subjective perception of muscle fatigue and the objective measures of MTF were evaluated before, immediately after and 15, 30, 60, 120 and 180 min after the work task (see Figure 4).

2.5. Muscle twitch fatigue

At each time period, first the muscle was stimulated for 120 and 180 s to reach the stable state of the twitch force after potentiation (Desmedt and Hainaut 1968, Rankin et al. 1988). Then, trains of 30 twitches

![Figure 2. Set-up of the work task. The hand grasped a vertical handle split into a fixed and mobile part that was adjusted for individual anthropometry and used to pull the required resistive grip force. This force, measured by the load cell, was displayed on a digital voltmeter.](image)

![Table 1. Exercise patterns.](table)
delivered at the frequency of 2 Hz were administered until three trains with a coefficient of variation of less than 5% were obtained (Adamo et al. 2002). The twitch force, defined as the difference between individual peak and baseline force levels was averaged over each train of 30 twitches and the average of the three trains determined the twitch force for that measurement time period.

2.6. Data analysis

An ANOVA was conducted to determine the main effects of age (young, old), gender, work task (S8, I20, I70) and interactions on the MTF response at selected time measurement periods. Two post-hoc analyses were also included. The Tukey-Kramer method was used to identify differences across work tasks and between the age groups, and paired t-tests were used to determine whether there were within group differences between pre- and post-work MTF measures. Fatigue was quantified by the maximal decrease in MTF, relative to the baseline measure obtained before each work task (% baseline) and recovery was assessed by the return of MTF to the baseline level. Comparisons between tasks were restricted to selected synchronous measures as an ANOVA including all time intervals, conditions and interactions does not present a meaningful significance. An ANOVA was also performed on subjective rating measures to determine the influence of the experimental conditions on subjective perception of fatigue over time. The level of significance was set at $\alpha = 0.05$ for each analysis.

3. Results

3.1. Control measures

The absence of significant differences ($p > 0.1$) in MTF over time in the control condition C_R and pre-work (T_C) measurements between days (C_R, S8, I20, I70) demonstrated the stability of the MTF within a day (control condition) and the high repeatability between days (pre-work measures across multiple days). The mean coefficient of variation of the pre-work twitch forces across experimental conditions was 10.5%. Hence, these results indicate that the pool of MUs recruited was stable and relatively constant across experimental days and allowed the comparison of experimental conditions using subjects as their own controls.

3.2. Muscle twitch force

The Tukey–Kramer test conducted on all post work MTF measures showed that there were no significant differences between genders ($p > 0.1$). This is in agreement with a previous result obtained for low-level exertion using the same MTF testing (Adamo et al. 2002); hence, analyses by gender were not necessary for the subsequent analyses.

Figure 3. Subjective rating of fatigue. Fatigue perception was indicated by placing a mark next to the most appropriate descriptor.

Figure 4. Experimental time line. Muscle twitch force (MTF), measures and ratings (fatigue rating (FR)) were taken once before and six times following the grip exertion work tasks. MVC = maximum voluntary contraction.
In young subjects, the largest decrease in twitch force was observed 15 min post work task in all conditions and persisted for 45 min in the sustained condition (Figure 5A). Paired t-tests, comparing the differences between control (Tc) and T15min within each condition, showed that decreases in MTF of 13% for S8 (t = 2.0), 9% for I20 (t = 2.2) and 8% for I70 (t = 2.2) were significant (p < 0.05). Despite a greater decrease in twitch force for the sustained exertion condition, the ANOVA (Table 2) indicates that differences between conditions at T15 were not significant. However, the decrease in twitch force persists until 60 min post work (T60) for the sustained exertion (p < 0.05), while recovery, shown by a progressive increase in twitch force, emerges after T15 for both intermittent exertion conditions with the twitches exceeding pre-exercise baseline values thereafter. The twitch force was significantly lower (p = 0.04) for the sustained than the intermittent exertion I20 at T60. In the sustained exertion condition, recovery does not appear to be complete until 3 h post work.

In the older group, the largest decrease in twitch force occurred 15 (T15) and 30 (T30) min post work in the sustained and intermittent exertion conditions (Figure 5B). Paired t-tests comparing the differences between TC and T15 values within each condition showed that decreases of 11% for S8 (t = 2.1) and 12% for I20 (t = 2.1) were significant (p < 0.05). At T30, decreases of 8% for S8 (t = 2.1), 13% for I20 (t = 2.1) and 10% for I70 (t = 2.2) were significantly lower (p < 0.05) than the baseline value. The ANOVA (Table 2) indicates that differences between conditions 15 min (p = 0.11) and 30 min (p = 0.17) post work task were not statistically significant. Recovery starts after T30 and is complete within 3 h. In the intermittent exertion conditions, recovery was complete between 1–2 h post work with the twitches exceeding pre-exercise baseline values thereafter. In the sustained exertion condition, full recovery was not complete until at least 2 h post work with the twitches exceeding pre-exercise baseline values thereafter.

3.3. Age effects
In the sustained condition, the older group showed a tendency of less fatigue and faster recovery when compared to the younger group (Figure 5A,B); however, these differences were not statistically significant (p > 0.3). The ANOVA (Table 2) did not reveal significant effects of age, condition and age × condition interaction on MTF.

3.4. Perception of muscle fatigue
A comparison between the age groups showed that differences in the perception of fatigue were negligible (p = 0.10). Hence, the results were pooled for both groups (Figure 6). Perception of fatigue doubled from 1–1.5 to 2.5–3 immediately after exertion in all conditions (p < 0.05) and 15 min later this perception was similar to the baseline value. This result indicates that the perception of heightened fatigue is of short duration, which contrasts with the objective measures of MTF. Tukey–Kramer comparisons indicate that there were no significant differences between conditions at any time interval (p > 0.05).
4. Discussion
The major findings of this study showed that, in context of low level mean grip exertions, MTF fatigue was induced by all work conditions. Fatigue responses were not significantly affected by age or gender as fatigue was moderate. Nevertheless, older participants showed a tendency towards less fatigue and faster recovery in the sustained exertion condition when compared to younger participants. In addition, fatigue was more pronounced in the sustained than intermittent conditions for the younger group. For all conditions and in both age groups, recovery was either complete or the muscle entered a potentiated/heightened state 3 h post work. Finally, a dissociation between subjective (FR) and objective (MTF) measures of fatigue was observed for all participants.

4.1. Fatigability
Considering the number of factors that may contribute to fatigue, such as muscle fibre composition, exercise training and metabolic rate, it is not surprising to find some variation in the fatigue response between individuals for low mean levels of exertion. In the present context, the potential systematic differences in the fatigue response may merit age-specific interpretations for the time profile of fatigue and recovery. In addition, as will be discussed below, other factors must be considered in order to compare the work task effects.

4.1.1. Intermittent vs. sustained conditions
The largest decrease in twitch force for the younger group was observed between 15 to 60 min post work task in the sustained exertion condition, with a nearly complete recovery after 180 min. In the older group, the maximal decrease in MTF (fatigue indicator) occurred at 30 min post work task with a nearly complete recovery within 120 min and then the muscle entering a potentiated/heightened state thereafter. Muscle potentiation, where the muscle output force increases for a given electrical impulse, is predominantly the results of type II muscle fibres and is thought to be a protective response to counteract fatigue. Fatigue was greater after the sustained than intermittent condition despite a lower mean force work task (8%MVC vs. 17%MVC) and a lower time tension product (120 vs. 150). Therefore, based on muscle work to characterise the exposures, these two results indicate that the MTF response and associated mechanisms are more strongly influenced by low-force static contractions compared to high-force intermittent contractions, suggesting that muscle work may not provide an adequate comparison between these two types of exertions.

4.1.2. Mean contraction and work
In similar work conditions, Bystrom and Fransson-Hall (1994) found that muscle fatigue persisted in the extensor digitorum communis (EDC) muscle 24 h after exposure to intermittent and sustained exertions using $\geq 17\%$ and $10\%$ mean work, respectively. These findings may appear to be in contradicition with the present results showing a faster recovery from fatigue. This, in part, may be explained by anatomical differences between the muscles in which the twitch force response is elicited. Three muscle groups (lumbricals, flexor digitorum profundus and superficialis) contribute to finger flexion force, whereas the EDC is the primary muscle generating force for finger extension. As a result, MTF quantified in the long finger compartment of the FDS may capture only a relative portion of the overall response of the muscle and may not quantify the contribution of other flexor muscles. In addition, the finger extensors have a small physiological cross sectional area compared to the flexors and are more sensitive to fatigue effects than

<table>
<thead>
<tr>
<th>Effects</th>
<th>df</th>
<th>$T_{15}$</th>
<th>F ratio</th>
<th>Prob &gt; F</th>
<th>$T_{30}$</th>
<th>F ratio</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (A)</td>
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<td>0.41</td>
<td>0.09</td>
<td>0.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work task (WT)</td>
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<td>0.81</td>
<td>0.54</td>
<td>0.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A * WT</td>
<td>2</td>
<td>0.08</td>
<td>0.92</td>
<td>0.28</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$df =$ degrees of freedom.

Figure 6. Mean perception of fatigue for both populations. The greatest perception of fatigue occurred immediately post work for all conditions, with greatest fatigue perception reported in the $S_8$ and $I_{20}$ conditions. This perception disappears within 15 minutes. *Significant differences. Bsln = baseline.
flexor muscles (Milerad and Kilbom 1985). Differences in electrical stimulation methodologies may also account for differences in the fatigue responses. The required low level grip exertions, 8% in the sustained and 20% in the intermittent exertions, respectively, may allow some ‘rotation’ within or between fingers and/or flexor muscles to compensate for fatigue and maintain the same resulting grip force. When the demands of the work task are of higher intensity, such as 25% MVC sustained and 40% MVC intermittent exertions (Bystrom and Fransson-Hall 1994), there may be less flexibility to redistribute the load within and between the finger muscles during the exercise. Hence, in these latter conditions, an increase in the overall fatigue response may occur and recovery may be slower.

As defined by the time tension product, despite greater muscle work, recovery took less time after the intermittent (k = 150) than sustained exertions (k = 120). This was more evident in the younger group (see Figure 5A,B). The differences in MTF and recovery time may result from differences in MU recruitment strategies, muscle composition of type I and type II fibres, intracellular ionic [K+, Ca++] concentration levels associated with excitation-contraction coupling mechanisms and/or blood flow during the contraction.

4.1.3. Motor unit recruitment strategies

MU recruitment strategies associated with fatigue and subsequent recovery have been found to vary with the level of muscle exertion within the intermittent/dynamic or sustained/static work component of the task (Marsden et al. 1983, Belhaj-Saif et al. 1996). For static exertions of 11–12%MVC (Jensen et al. 2000) or 30%MVC (Olsen et al. 2001), the recruited MUs fire continuously with no change in the mean firing rate. In addition, low levels of exertion static and slow dynamic contractions exhibit similar recruitment patterns (Sogaard 1995). However, fast dynamic tasks of high exertion (70%MVC) rely on an increase in MU recruitment and a high firing rate (Sogaard et al. 1998) to meet the required force output. From these findings, it may be inferred that similar MU behaviours are elicited, in their respective category, by the contractions tested in this study. Hence, it may be assumed that in all conditions the same pool of low threshold MUs is activated continuously; however, the number of MUs recruited and their firing rate, even for the same level of mean work, may vary between conditions. Differences in MU behaviours and a greater decrease in twitch force magnitude in sustained vs. intermittent exertion lead one to assume that MTF was related to long-lasting effects associated with decrements in the excitation-contraction process within the muscle and is not dependent on the way in which the force level is achieved. In that context, MTF and perhaps the post facilitation response seen in some conditions may be proportional to the net result of Ca++ and K+ concentrations, which affect the effectiveness of excitation-contraction coupling (Godt and Nosek 1989, Clausen and Everts 1991, Norton et al. 2001). In addition, the post facilitation effect may also be associated with a small decrease in MU recruitment threshold, which has been suggested to compensate for post exercise long-lasting effects of fatigue/low frequency fatigue (de Ruiter et al. 2005).

4.1.4. Excitation contraction coupling

The loss of K+ in transverse muscle membrane folds and accumulation of H+ ions that causes a decrease in Ca++ sensitivity of the myofilament result in a reduction of muscle tension (Godt and Nosek 1989, Clausen and Everts 1991, Norton et al. 2001). Furthermore, the restoration of K+ (Bystrom and Sjogaard 1991) and Ca++ in the sarcoplasmic reticulum is a slow process, which is likely responsible for slow recovery (180 min) as observed in this and other studies (Edwards et al. 1977, Bystrom and Kilbom 1990, Adamo et al. 2002). Oxygen depletion has also been associated with an increase in muscle fatigue (Murthy et al. 2001, Russ and Kent-Braun 2003, McNeil et al. 2006), which emphasises that blood flow is a critical factor contributing to muscle fatigue, even at low-level sustained exertions (Bystrom and Fransson-Hall 1994). The greater MTF decrease and slower recovery observed in the sustained exertion is likely to result from a greater extension of these phenomena, whereas intermittency challenges homeostasis to a lesser extent, as demonstrated by the I20 condition, which resulted in less overall fatigue and faster recovery. This hypothesis is in agreement with an absence of force limitation by blood flow during intermittent contractions (Wigmore et al. 2006).

4.2. Age effects

The age range used in this study targeted the working population in industrial settings and a distinction between 20–40 years and 50–75 year old participants was used to estimate differences in MTF and fatigability. Although the magnitude of twitch force reduction was similar in both populations, the recovery process in the sustained exertion tended to occur sooner for the older subjects. This population may be less sensitive to K+ loss as they rely on a larger number of slow, fatigue-resistant muscle fibres (Sears
Gender influences found in other studies (Fulco et al. 1999, Semmler et al. 1999, Hunter and Enoka 2001) are largely due to differences in force exertion levels (above 15% MVC), work duration (until exhaustion) as well as the method used to test fatigue (force and electromyography) and muscle tested. In these situations, there was strong evidence to support higher endurance levels for females, particularly at low–moderate force exertion levels (Zijdewind and Kernell 1994, West et al. 1995). However, a reduction in exertion capacity and changes in electromyographic spectra resulting from high level test contractions quantify short-term effects associated with the high frequency fatigue (HFF) investigated in these studies (Fulco et al. 1999, Semmler et al. 1999, Hunter and Enoka 2001) whose underlying mechanisms are different from those responsible for the long-lasting effects observed in this work. In addition, HFF methods lack sensitivity to identify long-term fatigue effects. Furthermore, in intermittent exertions requiring levels of exertion close to maximum, the relative fatigability of males and females is not significantly different for either young or old populations (Ditor and Hicks 2000). Although short-term fatigue effects may be gender related, the present study on long-term MTF fatigue resulting from low or moderate mean work does not support a gender difference in fatigability. Hence, the fatigue-induced changes in excitation-contraction coupling may not be gender specific as opposed to metabolic (Nygaaard 1981, Green et al. 1984, Tarnopolsky et al. 1990) and centrally (Hakkinen 1993) mediated mechanisms.

4.4. Perception of fatigue

In all conditions, the highest subjective ratings of muscle fatigue immediately after the work did not coincide with the greatest reductions in twitch force responses, which occurred 15 to 60 min later. This finding was consistent with previous work (Adamo et al. 2002) and confirms that the perception of fatigue may be more strongly associated with the short transient changes in voluntary force production and changes in electromyographic spectra, which displays faster recovery even after low level static and dynamic exertion (Moussavi et al. 1992) than the longer-lasting reduction of MTF. The inability to perceive the presence and persistence of long-lasting fatigue may be a limitation of the musculoskeletal system that may contribute, in conjunction with long time course for recovery, to cumulative effects leading to tissue disorders.

5. Conclusions

The present work suggests that the mean value of exertion over a work cycle is a parameter necessary, but not sufficient, to estimate the long-lasting effects of fatigue. The results confirm that a period of complete rest is an important factor to consider, even if brief, when designing work tasks. In addition, workers should be trained to avoid sustained exertions to reduce fatigue effects. Furthermore, in the context of low mean levels of hand exertions, fatigue responses were relatively similar between gender and age groups. However, the tendency of less pronounced fatigue and faster recovery from sustained exertion for older individuals suggest that age-related changes in muscle fibre type composition might increase resistance to the measured muscle fatigue. Hence, from the perspective of exertion only, ergonomic concerns about work tasks presenting similar patterns can be addressed in the same way regardless of gender and age. Finally, subjective perception of fatigue does not seem to be a reliable indicator of localised muscle fatigue.

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