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Muscle activity pattern dependent pain development and alleviation

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ABSTRACT

Muscle activity is for decades considered to provide health benefits irrespectively of the muscle activity pattern performed and whether it is during e.g. sports, transportation, or occupational work tasks. Accordingly, the international recommendations for public health-promoting physical activity do not distinguish between occupational and leisure time physical activity. However, in this body of literature, attention has not been paid to the extensive documentation on occupational physical activity imposing a risk of impairment of health – in particular musculoskeletal health in terms of muscle pain. Focusing on muscle activity patterns and musculoskeletal health it is pertinent to elucidate the more specific aspects regarding exposure profiles and body regional pain. Static sustained muscle contraction for prolonged periods often occurs in the neck/shoulder area during occupational tasks and may underlie muscle pain development in spite of rather low relative muscle load. Causal mechanisms include a stereotype recruitment of low threshold motor units (activating type 1 muscle fibers) characterized by a lack of temporal as well as spatial variation in recruitment. In contrast during physical activities at leisure and sport the motor recruitment patterns are more dynamic including regularly relatively high muscle forces – also activating type 2 muscles fibers – as well as periods of full relaxation even of the type 1 muscle fibers. Such activity is unrelated to muscle pain development if adequate recovery is granted. However, delayed muscle soreness may develop following intensive eccentric muscle activity (e.g. down-hill skiing) with peak pain levels in thigh muscles 1–2 days after the exercise bout and a total recovery within 1 week. This acute pain profile is in contrast to the chronic muscle pain profile related to repetitive monotonous work tasks. The painful muscles show adverse functional, morphological, hormonal, as well as metabolic characteristics. Of note is that intensive muscle strength training actually may rehabilitate painful muscles, which has recently been repeatedly proven in randomized controlled trials. With training the maximal muscle activation and strength can be shown to recover, and consequently allow for decreased relative muscle load during occupational repetitive work tasks. Exercise training induces adaptation of metabolic and stress-related mRNA and protein responses in the painful muscles, which is in contrast to the responses evoked during repetitive work tasks *per se*.

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1. Introduction

Muscle activity is a cornerstone in physical activity during work and leisure, and is for decades considered to provide health benefits irrespectively of the muscle activity pattern performed and whether it is during e.g. sports, transportation, or occupational work tasks. Accordingly, the international recommendations for public health-promoting physical activity do not distinguish between occupational and leisure time physical activity (Garber et al., 2011). However, in this body of literature, attention has not been paid to the extensive literature documenting e.g. occupational physical activity to impair health – in particular musculoskeletal health in terms of muscle pain (Punnett and Wegman, 2004). In spite of the lack of attention, this is not a novel recognition since already Hippocrates and Struensee posed these view points (Paffenbarger et al., 2001; Struensee, 1757), however, novel insights call for muscle activity patterns being revisited for their role in pain development versus alleviation.

2. Muscle activity pattern during daily life

Mechanical and metabolic responses to muscle activation and their interrelationship are crucial for identifying possible exposures at work and leisure that may cause muscle fatigue, exhaustion, dysfunction and pain. The latter additionally requests understanding of neural mechanisms and CNS centers facilitating or inhibiting the perception of pain. Basic knowledge on muscle mechanical responses includes the force–velocity and force–endurance relationships. In one end the force–velocity relation extends from zero velocity (=static contraction) and to maximal shortening velocity during concentric contraction with no or minimal force development. The rate of force development during static contraction is a proxy for measures of shortening velocity and has been shown to increase when motor units are stimulated by doublets – a means to increase contraction velocity of e.g. low threshold slow twitch muscle fibers (Sjøgaard and Søgaard, 1998). In the short term no pain develops with such contractions. On the other end of the force–velocity curve the eccentric contraction presents with maximal force development exceeding the static maximal voluntary contraction and may induce mechanical strain surpassing tissue strength resulting in micro ruptures. These may underlie the delayed onset muscle soreness, DOMS, regularly reported following intensive eccentric activity (Delfa de la Morena et al., 2013). Such pain may develop with a peak in intensity 1–2 days after the exercise bout and a total recovery within 1 week. For example, down-hill running, skiing, or stair walking, is causing pain in the quadriceps muscle that is mainly contracting eccentrically to brake the downward speed. Recent studies have demonstrated that such activity can acutely induce central pain sensitization but that repeated bouts of eccentric exercise facilitate inherent protective spinal mechanisms against the development of muscle soreness (Hosseinzadeh et al., 2013). However, such intensive eccentric contractions resulting in pain are rare in routine daily life activities and do not *per see* result in chronic pain conditions.

Daily life activities at work and leisure are for the most submaximal and repeated. Dynamic concentric contractions as well as static – sustained or repetitive – are the common patterns. The findings from moderate level of activity are in line with most physical activities at leisure and sport where the motor recruitment patterns are dynamic and regularly including relative high muscle forces – activating type 1 as well as type 2 muscles fibers – and allowing for periods of full relaxation. Such activities are unrelated to muscle pain development and are rather considered to be health enhancing.

According to the force endurance relationship these activities – when prolonged – will eventually cause fatigue and ultimately result in exhaustion. The latter, however, is rare in daily life activities but may play an important role in physical exercise training for rehabilitation or improvement of performance in conditions when relatively high training intensities are pertinent (Sjøgaard et al., 2014). Further, of utmost importance for maintaining or improving musculoskeletal health is the compliance to evidenced sports science training principles documenting that sufficient recovery is requested following exhausting activity.

3. Muscle activity pattern underlying chronic pain development

Static sustained and monotonous repetitive muscle contractions for prolonged periods often occur in the neck/shoulder as well as forearm area during occupational tasks and may underlie muscle pain development in spite of rather low relative muscle load. Causal mechanisms may include a stereotype recruitment of low threshold motor units (activating type 1 muscle fibers) characterized by a lack of temporal as well as spatial variation in motor unit recruitment (Sjøgaard et al., 2000). Aggravating factors are high forces combined with high repetitions that imply increased risks for development of musculoskeletal disorders, while the performance of tasks of moderate force level induced muscle adaptation (Barbe et al., 2013). The high force repetitive activity is likewise known from sports to result in musculoskeletal disorders as evidenced from terms such as tennis and golfers elbow.

Surprisingly, even tasks requesting only a low %MVC of the involved muscle's activation are extensively reported to elicit pain following long term performance. E.g. the use of computer input devices are generally considered to induce low load but unique detailed kinematic analysis resulted in several surprising findings challenging this classification.

In a laboratory setting 12 healthy right-handed subjects (4 females and 8 males) with a mean age of 35 (26–56) years, height: 1.72 (152–190) m, weight: 68 (50–85) kg, without medical history of shoulder or neck problems, volunteered in this study. They performed a series of double clicking with the mouse as well as a standardized computer task with repeated mouse clicking for 5 min at free work pace at two different circular shaped icon sizes: small (2 mm) and large (20 mm) on the screen. The mouse motion settings (Logitech MouseWare® 9.1 Windows) was set at 3 levels: medium (standard speed + acceleration setting), low, and high (i.e. lowest and highest possible motion settings, respectively). The study design was a complete 2×3 factor experiment with icon sizes: small and large, and mouse motion: low, medium, and high. Mouse, finger, and hand motion were monitored using reflective markers and the video based analysis system Peak Performance (Fig. 1). Surface EMG was recorded on the right side from the forearm muscle: *m.* extensor digitorum communis (EDC). EMG was analyzed as amplitude in % of maximal EMG amplitude during an MVC. The kinematic analysis showed that the accumulated distance of mouse – or finger – traveling was dependent on the mouse setting with the low speed resulting in the longest traveling distances. Further, the low precision demands (i.e. large icon size) resulted in longer traveling distance (Fig. 2). This implies that mouse settings could be optimized according to the task demands and that a mean traveling distance is in the order 2 m/min (Fig. 3). Thus, overall the accumulated horizontal traveling distance estimated for a 7 h workday with varied computer tasks was as long as 2 m/min $\times$ 7 h or approximately 1 km. Likewise the lifting height of the right index finger was analyzed. This was close to 1 mm per mouse click resulting in the accumulated vertical traveling distance for a 7 h workday with varied computer tasks to be as high as 0.001 m $\times$ 60 click/min $\times$ 7 h or approximately 25 m. These