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Choosing a mouse: what does the research say?

1.0 Introduction

It is now well known that musculoskeletal discomfort and other problems can result from computer use. The contributing factors to developing discomfort are multi-factorial and includes individual[1], psychosocial[2] and physical factors. Physical factors are those to do with the interaction of the workers with their physical work environment, for example, the postures and techniques adopted to do computer work. The term 'computer use' is usually used to refer to using the inputs of computer, that is, the keyboard, screen and input device, typically a mouse.

As computer use has increased over the years so too has musculoskeletal discomfort associated with it. The use of the mouse as an input device has been associated with the development of discomfort. This typically includes pain or discomfort experienced in the neck, shoulder, forearm and hand and may include specific disorders of these regions e.g. tendonitis. Discomfort and disorders can result in significant cost to both individuals and organisations. Efforts to prevent and manage discomfort have included seeking improvements in the use of the mouse, including its design.

Many mouse-type devices are available but the differences between them is often not clear. The traditional mouse is used with a 'claw' type hand position, where the palm and forearm face down. This is called full 'pronation'. Newer, alternative mice offer positions where there is less pronation of the forearm and hand, and the mouse is used in a more neutral position. In making a choice of mouse considering the associated benefits and drawbacks of these positions is important.

Following the explanation of the literature search strategy, this white paper aims to provide a summary of the peer-reviewed research to discuss:

[1] Individual factors include gender and level of general physical activity. For example, women develop discomfort more than men (e.g. Gerr et al. 2002; Juul-Kristensen et al., 2004; Karlqvist et al., 2002;) and physical activity has a protective effect in discomfort development, helps to manage symptoms and reduced absenteeism (e.g. van den Heuvel et al, 2005 Blangsted et al.,2008; Proper et al., 2006)

[2] Psychosocial factors are concerned with the interaction of individuals with the demands of their job and their work environment. For example, work demands, job control and social support are all associated with the incidence and development of discomfort (e.g. Devereux et al., 2002; Kryger et al.,2003; Jensen, 2003; Lassen et al., 2005; Polanyi et al.,1997).

- Can mouse use result in musculoskeletal discomfort? If so, what are the likely factors contributing to discomfort?
- How do traditional, pronated mouse designs compare with alternatives in terms of postures and musculoskeletal load?
- Can alternative designs help to manage discomfort?

2.0 Literature search

Four searches were performed in the SCOPUS[3] database with keywords and combinations shown in Table 1. SCOPUS is the largest abstract and citation database of peer-reviewed literature across the fields of science, technology, medicine, social sciences, and arts and humanities. These searches were repeated in the CINAHL[4] database to identify any additional potentially relevant references. CINAHL is a Nursing and Allied Health research database available on the EBSCOhost platform. Using these two database provides confidence that key literature is captured. Abstracts were read, and the full paper sourced if it was considered relevant. Additional relevant references were sourced from the reference lists included in articles and those already held by the author.

Table 1 Search strategy

Field code	Search no’	Keywords	Operator	Limits
Article title Abstract Keywords	1	Discomfort “computer mouse”	AND	English language Article, review article
	2	“computer mouse” “computer mice” “non-keyboard input device”	OR	
	3	“computer pen “pen-grip”	OR	
	4	“computer mouse” “mobile”	AND	

The following sections summarise the information available in the sourced literature.

[3] https://www.elsevier.com/solutions/scopus
[4] https://www.ebscohost.com/nursing/products/cinahl-databases/cinahl-complete

3.0 Incidence and contributing factors of discomfort with mouse use

Does mouse use lead to musculoskeletal discomfort? If so, what are the likely contributing factors? This section aims to address these questions.

3.1 Musculoskeletal discomfort

Using the mouse for prolonged computer activities has been associated with musculoskeletal discomfort in many studies in the 2000 decade. The types of mice used are not differentiated but the majority of mouse use occurs with traditionally designed mice and so the results apply to traditional mice. In fact, much of alternative mouse development has been in response to discomfort associated with using traditional mice. Kryger et al.'s (2003) prospective study found that the prevalence and incidence of right forearm pain was independently related to intensive use of the mouse device. Other studies also conducted around this time have expressed similar results (e.g. Jensen et al. 2002; Lassen et al. 2004). Most of the earlier studies used self-report measures to estimate duration. Research after this time eliminated self-report error with computer recording. Though this resulted in shorter durations of actual use,[5] associations between usage and discomfort were still found. Anderson (2006) found that the duration of weekly mouse use was associated with upper limb pain in the following week. Another associated study (Anderson, et al., 2008) found that the risk for acute neck pain and shoulder pain increased linearly by 4% and 10%, respectively, for each quartile increase in weekly mouse usage time. This finding is also supported more recently by Kiss et al. (2012) who found using the mouse for 50% or more of working time increased risk of neck and shoulder discomfort.

Ijmker et al. (2006) reviewed the longitudinal studies regarding the relationship between the duration of computer use and the incidence of hand-arm and neck-shoulder symptoms. They found moderate evidence for the association of mouse use duration for hand-arm symptoms and disorders but insufficient evidence for an association with keyboard use duration. There was a dose-response relationship found with this association, meaning there was an increase in risk as the duration of use increased. In support of these findings a later study also found some limited evidence that computer mouse time was associated with neck, forearm and wrist discomfort (Wærsted et al., 2010).

[5] Computer users have been found to overestimate the time they spend using the computer when self-reporting. This overestimation can be up to 4 times as much compared to video analysis or WorkPace® software (e.g. Homan & Armstrong, 2003; Heinrich, Blatter & Bongers, 2004)

Carpal tunnel syndrome, a specific disorder associated with median nerve entrapment at the wrist, has been associated with prolonged mouse use in some studies (Village et al 2005, Shiri & Falah-Hassani, 2014) though others have found insufficient evidence of computer work causing carpal tunnel syndrome (Thomsen, Gerr & Atorshi, 2008).

While not common place, additional conditions have been associated with prolonged mouse use. Ghasri & Feldman (2010) presented a case of frictional lichenified dermatosis[6] attributed, in part, to prolonged pressure and friction on the desk surface or mouse pad while using the mouse.

In summary, the research evidence is that using a traditional mouse can be associated with the development of upper limb discomfort or disorders. The longer the time spent using the mouse the greater the risk of experiencing discomfort.

3.2 What factors contribute to the discomfort associated with mouse use?

Several studies have tried to determine why using a mouse leads to discomfort. The areas that have been considered in the literature are organisational factors, forces, muscle activity, postures and techniques.

3.2.1 Organisational factors

Workplace stressors are now recognised as important risk factors for musculoskeletal symptoms (Bongers et al., 2006). This may be for several reasons including an increased physical load (e.g. increase muscle activity, higher forces, higher repetition, and awkward postures) due to these stressors. A fairly recent meta-analysis of computer use patterns and workplace stressors (Eijckelhof et al., 2014) showed some variation of mouse working technique depending on levels of workplace stressors. Workers with medium levels of reward moved their computer mouse significantly faster than workers with high levels of reward and workers with medium compared to low levels of over-commitment clicked significantly more times per minute with the mouse.

3.2.2 Forces

The force that is used to grip the mouse has been hypothesised as a potential contributor to discomfort. However, the forces applied to the mouse during regular work have been found to be low though women tend to exert more force than men (Johnson et al. 2000; Lindegård et al.

[6] Lichenoid dermatosis is the term used to describe any non-inflammatory skin disorder characterized by thickening and hardening of the skin.

2003.). It is not likely that musculoskeletal discomfort or disorders can result from these low force levels though they may play a part in muscular activity and load.

3.2.1 Muscle activity

Cooper and Straker (1998) found a trend towards higher muscular load for shoulder muscles during using the mouse compared to keying. Other EMG studies have found that more continuous and repetitive activity is present in the neck muscle on the mouse side than the non-mouse side (Jensen et al., 1999). In addition, muscle activity has been found to be higher when the mouse is used on the right with a keyboard that includes a numerical pad as this increases the distance the shoulder is positioned away from a neutral position (Cook & Kothiyal, 1998).

3.2.3 Postures and techniques

Deviations from 'neutral posture' with mouse use have been reported as increasing the likelihood of discomfort (Brown, Albert & Croll, 2007). Individual differences in postures and techniques have been identified in several studies (Burgess-Limerick et al. 1999; Cooper and Straker, 1998; Lee, McLoone & Dennerlein, 2008). Computer users assessed as having 'good' technique (using an assessment that included support of arms, movement of the mouse and posture) have been found to have decreased muscular load in the arms and neck with mouse use than users with 'poor' technique (Lindegård et al., 2003). This indicates a 'poor' technique may contribute to discomfort. Postures and techniques are determined, in part, by the design of the mouse used and the impact of design is considered in the next section.

4.0 Postures required for 'traditional' and 'alternative' mouse devices

Several studies have looked at different types of computer mice to determine the differences in postures and loads required depending on the design of the mouse. For this paper, these will be considered in terms of the traditional mouse and alternative mice with respect to forearm and hand position. The traditional style of mouse is where the mouse is used with the forearm and hand fully pronated, held with fingers and thumbs, buttons depressed with fingers and moved mainly with wrist movements. This includes trackballs, touchpads and various surface mouldings. Alternative mice are generally those that are used with less forearm pronation, in a 'handshake' position or a pen-like position, using fingers and/or thumbs for button activation and are moved mainly with whole arm movements (Gustafsson, 2003). Typical examples of these are vertical or upright mice, computer pens and a combination of these.

Biomechanics and ergonomics principles suggest that to use tools and equipment effectively, efficiently and with the least muscular stress joints should be used in 'neutral positions'

(Pheasant, 1991). This can also be defined as the resting position. For the lower arm this is when the forearm in a mid-position between full pronation (palm facing down on the desk with a bent elbow) and full supination (palm facing up on the desk with a bent elbow), the wrist in slight extension and fingers slightly flexed, and the thumb in line with the hand and slightly forward. Essentially, this is the pen-holding position that most people adopt. Using a mouse may activate muscles of the shoulder, forearm, wrists and hands. Reviewing the comparisons of traditional and alternative mice examined in the literature, the effects of design on muscle load, wrist movements and hand pressure are discussed in the next sections.

4.1 Traditional mice compared to vertical mouse

One of the first studies to spur development of alternative mice, Aarås & Ro (1997) investigating an early vertical mouse design, found that the muscle load on the forearm was less than with a traditional mouse. The authors suggested that this is due to reduced pronation required with the upright design. Following this, Keir et al (1999) found increased carpal tunnel pressure with three traditional mice. They postulated that this was a result of increased wrist extension with this design and the fingertip force applied to depress the buttons and to grip the sides of the mouse. They also suggested that a forearm not fully pronated may lead to slightly lower pressures when the wrist is extended to 20-30°.

Gustafsson (2003) demonstrated less ulnar deviation and less muscle load in work with a prototype mouse with a neutral pronation hand position compared to a traditional design. This was explained by the fact that this aspect of the hand is resting on the upright mouse during use. This contact, however, may be a negative in terms of contact pressure (Cobb & Cooney, 1995; Ghasri, & Feldman, 2010). The Gustafsson study (2003) attributed less wrist extension and frequency of deviation movements in the neutral posture to the design which encouraged whole arm movement rather than wrist movements. Also, they postulated that less muscle activity was because the neutral position is a more relaxed position.

Terming them ‘slanted’ computer mice, Chen & Leung (2007) compared five custom made mice with different angles in the palm position of the mouse. Thus, the slant angle altered the degree of hand and forearm pronation. They found that as the slant angle of the mouse increased (less pronation) the muscle activity of the hand, forearm and neck decreased relative to the non-slanted, traditional mouse. A 25° or 30° slant was optimal, this results in a mid-range pronated position.

Looking at a similar design, Odell & Johnson (2015) report on the comparative testing carried out for three concept mice with different angled top cases which led to the commercial production of the Microsoft Natural mouse 6000/7000. They compared the concept mice with the Evoluent vertical mouse and the more traditional Intellimouse Explorer. The vertical mouse reduced pronation but had the greatest wrist extension and poorer pointing performance. They found that the angled concept mice reduced forearm pronation and ulnar deviation though increased wrist extension slightly compared to the traditional mouse. In addition, they found that the contact area at the wrist was altered by the slight height and mid-range pronation. They suggested that this is another potential benefit of a more vertical mouse design in that it may reduce the contact pressure at the base of the palm (Odell & Johnson, 2015). Contact pressure has been identified as a possible consequence of mouse use (Ghasri & Feldman, 2010). The concept mouse which was rated more favourably by the users was used in the commercial product.

Feathers, Rollings & Hedge (2013) compared five mice including one vertical mouse (Evoluent) and one pronating reducing mouse (Microsoft Natural). Their results also showed that, in the traditional palm holding position, there is less pronation and less ulnar deviation, but more wrist extension. Similarly, Houwink et al., (2009) compared the traditional mouse with a pronation reducing alternative (Microsoft Natural Mouse). They found, again, less pronation with the alternative mouse than the traditional and higher wrist extension. Interestingly, this study added a training element, to teach the participants how to use the mouse optimally. Those in the 'trained' group exhibited less pronation and extension and lower muscle activity than those not trained. In addition, the trained group had less ulnar deviation and lower extensor muscle activity with the alternative mouse.

Gaudez & Cail (2016; 2017) also looked at slanted mouse, comparing musculoskeletal stress recorded between a traditional mouse, vertical mouse (Evoluent) and a slanted prototype. As with several of the other studies, they concluded muscle activity and ulnar deviation of the hand is lower with the alternative mouse design, though wrist extension is greater, than with the traditional design. The vertical mouse rated lowest on user-rated comfort and ease of use. Of note, they also tested the difference of muscle activity and performance with a change in the position of use of the mouse and found that using the mouse in front of the keyboard or freely moving it across the workstation improved these variables and resulted in lower muscle activity. This finding is supported by Kiss et al., (2012) noted that the position of the mouse is at least as important as usage time when examining development of discomfort.

In the most recent of research sourced Lourenço, Pitarma, & Coelho (2017) also compared the Evoluent vertical mouse and a traditional mouse in terms of performance and user ratings.

Their small study showed better performance and higher user ratings with the standard mouse. This finding has been repeated in many studies, with preference staying with the traditional design. This may be because the traditional mouse is ubiquitous in computer use and most people now are very familiar with it. Notably they found no correlation between the subjective discomfort variables and the objective useability parameters leading them to suggest that designing hybrid configurations of handheld pointing devices may be a better compromise.

4.1.1 Size

The effect of mouse size on postures and muscle activity were investigated by Oude Hegel et al., (2008). They compared five traditional mouse which differed primarily in size (75-105 mm long and 35-65 mm wide) with a reference, larger traditional mouse (121 mm x 64 mm). They found that the smallest mice results in less neutral postures with increased ulnar deviation, MCP flexion and wrist extension. Effectively, more hand 'hook'. Additionally, the smaller mouse evoked higher muscle activity in the wrist extensor muscles. Participants preferred the smaller mice for portability and the larger mice for comfort and useability. This indicates if the mouse is a smaller size the way in which it is held and used needs to differ from the traditional design to support optimal postures.

4.2 Traditional mice compared to pen-like mice

Several studies have used the idea of writing with a pen to develop alternative mice. The concept is based around the idea that an ordinary pen grip requires less static tension than that of a traditional mouse grip and that writing with a pen does not require wrist extension, ulnar deviation or extreme pronation.

Comparing a traditional mouse and a pen-tablet Kotani & Horii (2003) found significant less muscle load in the muscles of the hand with the pen, 5-10% less than with the mouse. There was also some reduction in the muscle load of the biceps with the pen (2.4%). In addition, this study found that the learning process to use the new device was short with high participant acceptance. This suggests that a pen-like position is intuitive and requires less muscle effort.

Ullman et al., (2003) developed a prototype mouse which mimicked a pen but including a moveable base, called the Ullman PenClic mouse. Their small-scale study compared muscle activity in mouse use between the pen-grip mouse and a two traditional mice. The pen-grip mouse showed reduced muscle activity in the neck and shoulder girdle muscles as well as forearm muscles compared to the traditional mouse.

Hedge & Chen (2004) then compared the Ullman PenClic mouse with another pen mouse (Salient V-mouse) and a traditional mouse. In this small study they found that these pen-mice reduced wrist pronation and ulnar deviation compared to the traditional mouse though showed an increase in wrist extension. Moreover, the performance of the pen-mice was equivalent, and preferences were overall more for the pen-mice than the traditional mouse.

More recently, the I-pen was compared to a traditional mouse (Müller, Tomatis, & Läubli, 2010) and muscle activity and performance examined. The I-pen uses a force sensitive tip for left mouse click and a multi-functional bottom on the top back for scrolling and right mouse click. This study found no differences in muscle load of the trapezius between the two devices. Interestingly, they found that learning allowed for near equal performance of both devices. The effort required by both the hand and the shoulder to use the I-pen was not perceived to be harder than the mouse.

Using a prototype vertical mouse of a vertical rod on a base, again based on the biomechanics of handwriting, Quemelo & Vieira (2013) compared positions and muscle activity with a traditional mouse. This small study found significant lower muscle activity in the extensor muscles with the vertical mouse, less pronation and ulnar deviation though extension movements were greater. The authors suggested improvements to their prototype of reducing button force, including a scroll wheel, decreasing the base size and adjusting the handle to allow the arm to rest on the table.

In another small-scale prototype development study, a vertical mouse based on pen-grip principles (Ergomice) was compared on aspects of performance and user-rated comfort (Dehghan et al., 2015) with a traditional mouse, a pen mouse and a track-pad. They found performance (task completion time and error rate) and comfort better with the traditional mouse with the Ergomice out-performing the pen-mouse and the trackball on these measures.

4.3 Summary

Considering the available evidence described above it can be suggested that,

- Vertical mice design, compared to traditional design, decreases pronation, ulnar deviation and muscle activity but increases wrist extension.
- Vertical mice design tends to be preferred less than traditional design. Most likely due to familiarity.
- Small, traditional design mice increase non-neutral postures.

- The ability to position the mouse freely in the workspace decreases muscle load.
- Pen-like mouse design compared to traditional design, decreases pronation, ulnar deviation and muscle activity but tends to increase wrist extension.
- Pen-like mouse design seem to be more accepted than vertical mouse with a short learning time.
- Alternative mouse design with less pronation can reduce contact pressures.

5.0 Can using an alternative mouse change discomfort?

Considering if using alternative mice impacts on discomfort in the long term in the 'real world' is generally not well researched given the complexities of longitudinal, intervention studies. However, Aarås, Ro & Thorensen (1999) provided a vertical mouse to a group of people experiencing discomfort and after six months they reported a significant decrease in pain intensity and frequency for the neck, shoulder, forearm and hand compared to the control group. As a follow-up to this study they then provided the control group the vertical mouse and after a further six months this group also reported significantly less pain in the shoulder, forearm and hand (Aarås, Dainoff, Ro & Thorensen, 2001). In addition, re-evaluation of the initial intervention group after one year reported no increase in pain intensity. This study showed that an alternative mouse with less pronation can influence recovery from musculoskeletal discomfort associated with mouse use. Moreover, this reduction in discomfort is sustained.

Another intervention study (Conlon, Krause & Remple, 2008) all eligible employees completed an initial questionnaire and then consenting computer-based engineers were randomly allocated to one of four intervention groups. They either received a traditional mouse, a vertical (Renaissance) mouse, a traditional mouse with a forearm support board or a vertical mouse with a forearm support board. Baseline measures of discomfort and other factors were recorded, and the study participants were tracked over 52 weeks. This study concluded that provision of forearm support may reduce right upper extremity discomfort. While not statistically significant, there was a trend for the vertical mouse to reduce neck /shoulder discomfort and right upper limb musculoskeletal disorders. These studies suggest that there is an opportunity to reduce and manage musculoskeletal discomfort related to mouse use with mice that are different to the traditional mouse and, in particular, reduce pronation require for use.

6.0 Conclusion

When choosing a mouse, the research suggests:

- A traditional mouse design, which requires a fully pronated hand position is a contributor to discomfort related to computer use.
- Vertical mouse designs in neutral pronation decrease pronation and muscle activity but increase extension and seem to have performance and acceptance issues compared to traditional designs.
- Designs reported in the literature using pen-like positions show reduced pronation, ulnar deviation and muscle activity though increased wrist extension. A pen-like position design which limits wrist extension would be desirable.
- Pen-like position designs seem to have better acceptance than vertical mice. Acceptance may be improved if the design included aspects of the functionality of traditional mouse e.g. moveable base, buttons and scroll wheel.
- Smaller mice are preferred for portability and may improve the ability to change where mouse is used on the worksurface, e.g. in front of keyboard, which improves neutral shoulder positions, but if the mouse is a small version of the traditional design they may compromise hand position and increase muscle loading.
- A slightly, higher mouse with a mid-range pronation position may reduce contact pressure with the work surface.
- Training in how to use the mouse helps to optimise technique and reduce muscle activity.

Alternative mice, if designed considering the points above, offer one potential way to prevent and manage musculoskeletal discomfort related to mouse use.

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