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Towards evidence-based guidelines for wise use of computers by children

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Abstract

This paper argues for the systematic development and presentation of evidence-based guidelines for appropriate use of computers by children. The currently available guidelines are characterised and a proposed conceptual model presented. Five principles are presented as a foundation to the guidelines. The paper concludes with a framework for the guidelines, key evidence for and against guidelines, and gaps in the available evidence, with the aim of facilitating further discussion.

Relevance to industry

The current generation of children in affluent countries will typically have over 10 years of computer experience before they enter the workforce. Consequently, the primary prevention of computer-related health disorders and the development of good productivity skills for the next generation of workers needs to occur during childhood.

Keywords: Children; Computers; Health; Learning

1. Introduction

Computer use by children in affluent countries has risen rapidly over the last decade and in many countries there are very few children who have not used computers. For example, 95% of Australian children aged 5–14 reported using a computer in the 12 months to April 2003 (Australian Bureau of Statistics, 2005). This computer use was at both school (89%) and home (82%). European data shows a clear positive relationship between computer access at school and home (Eurydice, 2004). Across Europe, computer access at home is related to household income; and school computer access is related to per capita gross domestic product (GDP, Eurydice, 2004). Aside from affluence, home computer access is also related to parental study and work status and attitudes to education and technology (Straker et al., 2006). School computer access is also related to national education priorities. Consequently, home access varies from around 85% in countries such as South Korea and Sweden to very low levels in less affluent countries. Similarly, school access varies from 100% in countries such as Singapore to very little in less affluent countries. Whilst limited data on computer use is available for less affluent countries, basic data on numbers of computers per 100 inhabitants reveals the range (Asia-Pacific Development Information Program). Thus in countries such as India (0.6 computers/100 inhabitants) and Indonesia (1.01) child access and use of computers is likely to be far more restricted than in countries like China (11), Malaysia (12.61), Australia (25.6) and Japan (34.9).

Computers are also being found in devices other than the traditional desktop and laptop computers, such as palmtop personal digital assistants (PDAs), smart phones and Internet fridges. In this paper, however, we will focus on children's use of desktop and laptop computers.

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1.1. Knowledge of consequences for adults has been superseded

Rapid expansion in adult use of computers in the 1980s saw significant social and health impacts. This led to national and international standards and guidelines such as the International Standards Organisation ISO 9241 (International Organization for Standardization, 1997), European Community Council Directive 90/270/EEC (European Agency for Safety and Health at Work, 1990), and the Australian National Code of Practice for the Prevention of Occupational Overuse Syndrome (National Occupational Health and Safety Commission, 1996). We believe these guidelines are of limited utility for guiding the use of computers by children for the following reasons:

- Physiological and biomechanical differences between children and adults.
- Differences in the way children and adults use computers.
- Limited evidence base used for adult guidelines.
- Changes in technology since early research and guidelines (1980s).
- Better measures of physical impact are now available.

Much of the adult literature on the biomechanical and physiological responses to computer use, which was used as the basis for current guidelines, was conducted during the 1980s. Many aspects of this research are now out of date due to changes in computer hardware (e.g. a variety of pointing devices, and larger displays are now common and these both have significant implications for postural and muscle use patterns), computer software (e.g. Graphical User Interfaces which require pointing device use are now ubiquitous), workstation design (e.g. partially wrap around desk now promoted in Scandinavia—which changes loading on shoulders) and work organisation (e.g. increased number of tasks performed on computer—which reduces need to change posture; increased use of computers by non-computer specialists; increased integration of paper and electronic media in information technology (IT) tasks); and increased use of computers in locations other than traditional workplaces.

1.2. Guidelines specifically for children's use of computers needed

Computer use by children has been claimed to have both beneficial and detrimental effects (Ford-Jones, 2003; Straker and Pollock, 2005). Beneficial effects proposed have included enhanced learning, social interaction and fine motor coordination. Detrimental effects proposed have included addiction, social harm, visual problems and musculoskeletal disorders. We believe that child specific guidelines should be developed to optimise the interaction between children and computers thus maximising the benefits and minimising the detrimental effects.

Promoting wise use of computers by children may be particularly important as there may be more potential to change—both in terms of physical structure and habits and mental approach to computers—in a developing individual.

At the International Ergonomics Association (IEA) congress in 2003 we proposed a pathway for developing evidence-based guidelines (Straker and Pollock, 2005). This pathway was built on the principles of:

- transparent supporting evidence—providing levels of evidence for each guideline,
- living—ensuring the guidelines are modified and adapted in the light of new evidence and use of technology,
- culturally sensitive—ergonomics has too frequently assumed European and North American cultures as the norm,
- not limited to current technology—principles should help guide new technology development,
- balancing outcomes—where there are tradeoffs, for example between cognitive and musculoskeletal development, and
- edited to suit target groups—such as equipment manufacturers, schools, parents, children.

We particularly argued that there were dangers associated with being too quick to promote unsupported guidelines—and losing the trust of the public. We also identified the risk of ergonomists being too conservative and awaiting unquestionable proof—and losing the ear of the public and government to other lobby groups willing to sell simplistic messages in order to gain media attention.

1.2.1. Levels of evidence

To balance respect for science and the need for guidance we proposed the publishing of levels of evidence and currency of evidence along with each guideline.

A number of systems for rating the level of evidence have been published, some of which are limited in scope in terms of the type of evidence they deal with as they arose out of medical trials literature. To be suitable for ergonomics, the levels of evidence system needs to encompass a wide range of studies useful in providing evidence—from epidemiological studies through in vivo studies, to computer modelling studies. For this paper we will use the system we published in 1999, as summarised in Table 1. Thus for each guideline we believe there should be a summary of the available evidence and an overall rating of the level of that evidence (see example later in paper).

The currency of the evidence also should to be reported. We suggested adopting the approach used by departments of foreign affairs to demonstrate the currency of travel alerts. For example the Australian Department of Foreign Affairs adds a "current for (today's date)" and when the alert was last reviewed and when it was last changed. In the

Table 1
Hierarchy of levels of evidence for ergonomics studies (adapted from Straker (1999))

Rating	Definition
*****	Excellent: Evidence is provided by complimentary evidence from rigorous studies replicated across population of interest thus demonstrating wide generalisability
****	Very Good: Evidence is provided by either: –a very high quality study—with strong design (e.g. randomised controlled trial, sequential clinical trial, factorial or repeated measures, single case studies with replication), using measures with demonstrated reliability and validity, rigorous data collection and appropriate analysis –or multiple level *** studies using different approaches (i.e. not sharing the same errors)
***	Good: Evidence is provided by a moderate quality study which is basically sound but with possible caveats (e.g. presumed reliability and validity of measures or weaker 'cause-effect' evidence due to design [survey, AB single case design, phenomenology])
**	Some: Evidence is provided by reflective practice, case study
*	Minimal: Evidence is provided by expert opinion, reasoning, case description
—	None: No evidence is provided by tradition, novice opinion, poor quality study (for example one with serious design flaws [finding no effect due to insufficient power], one where dependent variable measurement was not reliable and valid, one where data collection was sub-standard)

example guidelines we provide below we have attempted to incorporate this information.

The first step on the pathway we proposed was peer review and discussion of the basic principles and specific guidelines. The prime purpose of this review was to identify invalid or obsolete assumptions and guidelines and identify gaps in the available evidence.

Therefore the aim of this paper is to progress down the path to evidence-based guidelines for wise computer use by children by providing an opportunity for international discussion emphasising the evidence base for each guideline. The paper reports on currently available guidelines then provides a framework for the discussion. At the CybErg 2005 conference we hosted a discussion on this paper and have prepared a Technical Note summarising some of the discussion (Straker et al., this issue). The focus at this stage of development is on generic guidelines which would be subsequently developed into audience specific guidelines.

2. Available guidelines

In early 2005, we conducted a search of Internet sites, firstly focused on child computer use specifically and then broadened to include adult computer use. Using the Google™ search engine there were over 72 500 hits using keywords "child computer ergonomic guidelines."

In reviewing the available guidelines it became apparent that there were at least four basic types:

- fraud protection,
- social protection,
- education/software selection,
- workstation set up.

Fraud protection guidelines typically included how to protect against virus attacks, financial scams and privacy invasions. Social protection guidelines typically included how to protect against paedophiles/stalkers, violence and pornography. Education guidelines often included how to select age appropriate software and use computers for cognitive development. Workstation set up guidelines typically included how to appropriately use the desk, chair and computer to encourage good working postures.

The guidelines were produced by a range of authors including:

- technology companies,
- government departments,
- professional organisations,
- individuals with an interest in the area, and
- self-help and community groups.

Technology companies included computer manufacturers (e.g. Apple Computer Inc., 2005; IBM Corporation, 2005), software companies (e.g. Microsoft Corp., 2003), Internet service providers (e.g. Telstra BigPond Australia, 2005; Yahoo! Inc., 2003). Government departments including education authorities and library services had child guidelines. Government broadcasting and media authorities also provided guidelines and health and safety departments (Better Health Channel, 2001; Queen's Printer for Ontario, 2004) and standards organisations had adult guidelines (European Agency for Safety and Health at Work. 1990; Occupational Safety & Health Administration, 2005). Professional organisations included the IEA through its technical group Ergonomics for Children and Educational Environments, regional ergonomics groups and physiotherapy (California Physical Therapy Association, 2003) and occupational therapy (The American Occupational Therapy Association, Inc, 2005) associations. Some concerned individuals with a professional interest in the area have developed and published guidelines (e.g. Ankrum, 2005; Computer Ergonomics for Elementary School (CergoS), undated; HealthyComputing.com, 2001; Hedge, 2004; Lueder, 2004). Self-help groups included groups for people suffering RSI (e.g. CTD Resource

Network, Inc, 2002; Quilter, 2003), computer user groups (e.g. Melbourne PC User Group, 2004) and parenting support groups (e.g. BabyCentre, 2004; NetAlert Limited, 2005; RTSG Inc., 2004; WiredKids.org, 2004). Other interesting websites included:

Cybersmartkids (Australian Broadcasting Authority, 2001),
Young Media Australia (Young Media Australia, 2002),
Kidshealth (The Nemours Foundation, 2005),
Sesame Workshop (Sesame Workshop, 2005).

There appeared to be a high level of consensus for many areas of guidelines. However there were some clear areas of discrepancies. These differences extend to whether or not children should use computers at all. For example an RSI self-help site states "…the best way to prevent computer-related injuries in children is not to allow them to use computers at all" (Quilter, 2003). This is in stark contrast to the vision of the European Commissioner for Education and Culture who stated "All schools, if not all classes, should be highly computerised, all teachers should be able to use the technology to enhance their working methods and all young people should be able to broaden their horizons by using it comfortably though with the necessary critical perspective" (Eurydice, 2004).

Other controversial areas we expect will generate international discussion include:

- How long should children use a computer at each sitting and each day?
- How much support should a seat provide?
- At what height should a display be positioned?
- At what height and angle should a keyboard be positioned?
- Should the forearms be supported?

Developing evidence-based guidelines should minimise the controversy, as long as there is a shared conceptual model.

3. Model basis for guidelines

Fig. 1 illustrates the conceptual framework of the child–computer interaction upon which our guidelines are based. The child–computer interaction typically occurs in school and in home environments; with parents and siblings being important elements in the home environment and teachers and peers important in the school environment.

Appropriate management of the child–computer interaction should lead to positive effects in a number of domains including social and cognitive development. Unsuccessful management may lead to damage to the computer and the child. Computer damage may arise from unsuccessful guarding against hacking and viruses. Harm to the child ranges from financial loss through personal abuse and injury to inappropriate social development and damage to vision and musculoskeletal systems.

4. Towards evidence-based guidelines

As a first step towards evidence-based guidelines we present a framework for wise computer use guidelines. The framework consists of five main principles aimed at ensuring a positive outcome from child–computer interaction. Each principle is described briefly.

The principle related to physical health issues is expanded to provide a framework for more detailed discussion. We propose three principle guidelines under the physical health principle. During the conference we facilitated a discussion on each of these guidelines. For each recommendation under each guideline we welcomed

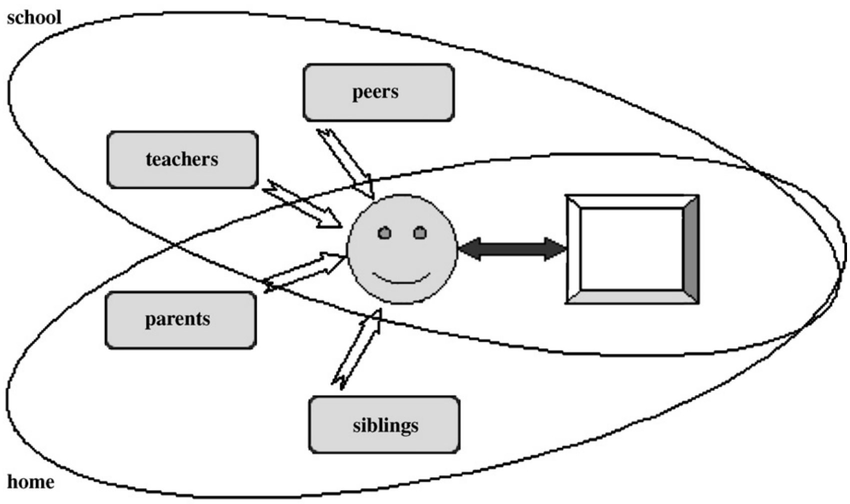

Fig. 1. Child–computer interaction model.

detailed comment on the evidence available for and against and what evidence is missing.

4.1. Maintain technology safety

The viability of the child–computer interaction is threatened if the computer system is not adequately protected against unintentional software damage by the child user or intentional damage by external hackers either directly or via virus/worm programs. Wise use of computers needs to encourage appropriate protection of technology.

4.2. Maintain personal safety/privacy

The child (and their family) may be harmed by financial fraud—with e-mail spam scams very common. Children may also be lured into financial transactions via on line advertising. Music and video piracy and copying are illegal activities currently common amongst young people using computers. Computer use also provides opportunities for other unethical or undesirable behaviours such as plagiarism and gambling. A major personal safety issue is the potential to contact people with paedophilic or other abuse intent. Wise use of computers by children needs to ensure adequate safety of each child.

4.3. Encourage appropriate social development

Computer use provides opportunities for positive social experience. 'Netiquette' guidelines encourage children to learn and use socially acceptable rules of social interaction. Computer use allows children to find new friends and break out of current constraints on their interactions such as their physical appearance. However computer interaction can expose children to observation and participation in violence, cultural and gender stereotyping, bullying and pornography. There is some concern that some children may have impeded social developed due to an "addiction" to computer interaction. Wise use of computers by children needs to encourage positive social development.

4.4. Facilitate appropriate cognitive development

Computer use, particularly with Internet access, provides opportunities for children to access potentially inappropriate content such as drug use, bomb making and suicide methods. However computer use has also been demonstrated to assist cognitive development in the areas of literacy, numeracy, problem solving and subject specific content through the use of age appropriate software and content. Wise use of computers needs to facilitate appropriate cognitive development.

4.5. Facilitate appropriate physical stresses

Desktop and laptop computer use is commonly sedentary, often seated at a desk (though with laptop computers other seated, lying and standing postures may be common) (Harris and Straker, 2000). Whilst there are more and less appropriate sedentary postures, any sedentary posture which is maintained for long periods is likely to result in unacceptably high physical stresses on some tissues due to limited opportunity for recuperation; and undesirably low stresses on the body as a whole. As the response to physical stresses is dependant on both the task demands and the individual's capacity, improving the child's physical capacity is desirable.

Following is an example of the guidelines for facilitating appropriate physical stresses. During the conference we used this as the structure for discussion on which guidelines to include.

4.5.1. Encourage mix of whole body movement tasks and sedentary tasks
- 4.5.1.1. Encourage task variety
- 4.5.1.2. Encourage use of active input devices e.g. dance mat, EyeToy™
- 4.5.1.3. Encourage postural variety (pause exercises of limited utility)
- 4.5.1.4. Limit sedentary use of computers to *n* hours a day

4.5.2. Encourage reasonable postures during sedentary tasks
- 4.5.2.1. Encourage the use of a range of suitable postures by providing adjustable workstations (and not drop-down keyboard trays or anything else which restricts the range of possible postures)
- 4.5.2.2. Set chair to leg length, possibly with back rest, possibly a dynamic seat, not too comfortable seat, possibly with arm support
- 4.5.2.3. Set desk to around elbow height, possibly curved, with sufficient space for papers
- 4.5.2.4. Set display position to below eye height, directly in front, as far away as possible while still able to read text, without glare/reflection, perpendicular to line of sight
- 4.5.2.5. Set controls—keyboard and mouse close to trunk or with arms supported, size to suit, shape to suit

4.5.3. Facilitate skill and fitness of child
- 4.5.3.1. Learn to touch type with minimum force
- 4.5.3.2. Respond to discomfort immediately

4.6. Examples of limitations of current evidence

Two examples of where the available knowledge is insufficient are the impact of desk design on forearm support and the impact of display position on neck posture (Burgess-Limerick et al., 2000). Table 2 provides a

Table 2
Example of evidence for desk design and forearm support

The traditional guidelines for computer use have required the user to sit upright and have free upper limbs to operate a keyboard input device. In this posture small amounts of gleno-humeral flexion or abduction can greatly increase neck and shoulder muscle loading and resultant discomfort (Straker et al., 1997). The use of a mouse can exacerbate this problem (Cooper and Straker, 1998).
Earlier research in light industry and dental care settings had found that supporting or suspending the elbow could reduce neck and shoulder muscle loading (Milerad and Ericson, 1994; Schuldt et al., 1987). Based on this research, Aaras et al. (1997, 1998), conducted a laboratory study and then a controlled field trial on computer operators with and without full forearm support. The laboratory study showed that full forearm support, as provided by a horseshoe shaped desk, did reduce trapezius muscle loading during keyboard operation. The effect of full forearm support during use of a computer mouse was not determined. The Aaras et al. field study demonstrated a reduction in shoulder discomfort after provision of a horseshoe shaped desk.
Current office work practices commonly include both computer and paper-based IT tasks at the same desk, yet no studies have evaluated a desk for both types of task.

Table 3
Example of evidence for display location and neck posture

The head and neck system comprises a rigid head located above a relatively flexible cervical spine. Flexion and extension are possible at the atlanto-occipital and cervical joints. The ligaments and joint capsules allow a large range of movement without significant contribution from passive tissues. The centre of mass of the head, and the head and neck combined, is anterior to the atlanto-occipital and cervical joints. Consequently, extensor moments about the atlanto-occipital and cervical joints are required to maintain static equilibrium when the trunk is vertical. A large number of muscles with diverse sizes, morphology and attachments are capable of contributing to these moments. The suboccipital muscles, which have origin on C1 and C2 and insert on the occipital bone, are capable of providing extensor moment about the atlanto-occipital joint only; others (e.g. semispinalis capitis) provide extensor moment about cervical as well as atlanto-occipital joints; while others (e.g. semispinalis cervicus) provide extensor moment about cervical vertebrae only.
When the trunk is approximately vertical, an increase in flexion of the atlanto-occipital joint and the cervical spine increases the horizontal distance of the centre of mass of the head and neck from the axes of rotation in the vertebral column (and all else remaining the same, the horizontal distance of the head from its axis of rotation). Hence, with the trunk approximately vertical, both atlanto-occipital and cervical flexion (which occurs in response to lowering the height of computer displays) increases the moment required of the extensor musculature to maintain static equilibrium. The conventional view, based on the analysis above, is that an erect head and neck posture that reduces the flexor moment of the head will reduce neck discomfort. According to one model Snjiders et al. (1991), neck *extension* of 30° places the centres of mass approximately over the axes of rotation and reduces the external flexor moment required to resist gravitational acceleration to zero. This logic has prompted recommendations to increase the height of visual targets such as computer displays in order to increase neck extension and reduce muscular effort De Wall et al. (1992).
Whilst such a simplified model of the situation is intuitively attractive, the cervical spine is particularly complex and inherently unstable in the upright position (Winters and Peles, 1990). Additional co-contraction is required to increase the stiffness of the cervical spine and prevent buckling. Significant muscular activity is probably required to stiffen the cervical spine, even if the head and neck are positioned to minimise the flexor moment imposed by gravitational acceleration. Indeed, the necessity for muscle activity to stabilise the cervical spine is likely to be greater when it is relatively extended (Winters and Peles, 1990).
The tension-generating capability of a muscle is highly dependent on its length. Extension at the atlanto-occipital and cervical joints will alter both the moment arm and the average fibre length of muscles actively providing both the required extensor moment and stiffness. The suboccipital muscles in particular are relatively short and even a small change in average fibre length caused by extension of the atlanto-occipital joint is likely to cause significant decrement in their tension-generating capabilities. Yet it is precisely these muscles which appear to be primarily responsible for vertical movements about axes high in the cervical spine (Winters and Peles, 1990).
Prior studies on superficial neck muscle activity during reading from paper or working with computers have yielded varied results. Schuldt et al. (1987) for example demonstrated elevated myoelectric activity (EMG) in the posterior neck musculature during maximal flexion but no significant differences for intermediate postures, while Harms-Ringdahl et al. (1986) did not detect EMG differences between neutral and extreme flexion.
More recent results have consistently found a positive relationship between superficial cervical erector spinae activity and head flexion (e.g. Greig et al., 2005; Saito et al., 1997). However there appears to be no consistent relationship between upper trapezius activity and head flexion (e.g. (Greig et al., 2005; Saito et al., 1997).
The available biomechanical and EMG data does not provide sufficient evidence to determine an optimal posture (or range of postures) of the head and neck due to the simplistic nature of biomechanical and physiological measures taken and the failure to consider the use of both paper and computer interfaces.

summary of the evidence for desk design and forearm support and Table 3 provides a summary of the evidence for display location and neck posture. Additionally, improved measures to characterise physical stress are now available which can provide new evidence, as summarised in Table 4.

4.7. Examples of limitations of current evidence

Table 5 provides an example of what we consider should be provided for every guideline to adequately capture and report the evidence for that guideline. During the conference we asked participants to nominate key evidence

Table 4
Example of better measures to provide evidence of physical stress

The European Community and the USA government have commissioned reviews of the epidemiological, human laboratory and animal model evidence that increased postural stress and increased EMG are risk factors for musculoskeletal development (Bernard, 1997; Buckle and Devereux, 1999; National Research Council, 1999). Whilst there is continued debate concerning the aetiology of activity related musculoskeletal disorders, the reviews unanimously found there was sufficient evidence to accept postural stress and increased EMG as risk factors.

The measures of biomechanical stress previously used have been estimates of joint loadings based on two-dimensional (2-D) posture analysis. The neck has typically been considered a rigid segment with hinge joints at atlanto-occiput and C1–C7. From the discussion on display height it can be seen that more detailed and 3-D analysis needs to be conducted. Recently a more anatomically detailed model of the neck region has been developed (Vasavada et al., 1998) using advanced 3-D modelling software (MusculoGraphics, USA).

The measures of physiological stress previously used have been amplitude and median frequency of EMG from superficial muscles (typically upper trapezius and cervical erector spinae group). Recent studies have found that not only is the amplitude of EMG important, but so is the pattern of activation duration. It has been suggested that amplitude and pattern of duration may interact and a method of dealing with both aspects simultaneously has been developed (EVA—Exposure Variation Assessment, Mathiasson and Winkel (1991)) but is yet to be used to evaluate computer use postures.

Table 5
Example of evidence-based guideline with summary, rating and currency of evidence

Guideline xx.xx	Place display so that the centre of the display is 20° or more below horizontal eye height
Key evidence:	epidemiological evidence of a link between sustained neck flexion and MSDs is provided by … … Laboratory evidence that sustained neck flexion increases extensor sEMG and gross moments provided by … … However theoretical arguments have been made to challenge a simplistic model of more flexion equates to more stress …
Limits of evidence	Evidence from laboratory studies limited as no definitive evidence that sEMG or posture actually relate to MSD, short-term responses may not reflect long-term conditioned response, and better characterisation of physical stress including stress on deep neck tissues is required. Evidence applicable to CRT, TFT, Plasma display technologies around 40 cm diagonal in size
Summary	Current studies suggesting less head/neck flexion are not consistent with simplistic models (optimal position suggested is not 30° extension) therefore better characterisation of physical stresses required before evidence-based guideline can be promoted
Star rating	***
Advice current for	May 2005
Last edited on	31 April 2005
Originally prepared	21 April 2005

and contribute to the discussion on the limitations and summary of the evidence.

5. Conclusion

This paper has presented a framework for developing evidence-based guidelines for wise use of computers by children. During the conference we hosted a discussion on the 5 principles listed, with a focus on physical health and computer workstation guidelines. We encouraged conference participants to actively engage in the discussion by suggesting additional guidelines, nominating key studies which provide evidence for each guideline and suggesting shortcomings or omissions in the available evidence.

This paper, and the related Technical Note summarising some of the discussion at the CybErg 2005 conference (Straker, this issue), provides the basis for a draft set of guidelines. Following further peer review, these guidelines should be submitted to evaluation via implementation in randomised and controlled trials.

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